MANUAL No. 3

TECHNICAL EQUIPMENT OF THE SIGNAL CORPS

1916

WAR DEPARTMENT - - OFFICE OF THE CHIEF SIGNAL OFFICER

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INTRODUCTORY.

This manual, which supersedes Manual No. 3, edition of 1910, and Manual No. 4, Handbook of Submarine Cables of the United States Signal Corps, 1905, relates principally to the latest technical equipment of the Signal Corps issued for field use of the mobile army, and to the technical equipment installed at mobile army posts. An enumeration of all Signal Corps equipment appears in chapter 8.

Fire-control systems and their equipment are described in Signal Corps Manual No. 8, latest edition.

Technical information relative to radiotelegraphy and equipment is embodied in "Radiotelegraphy" (Signal Office Circular No. 1).

Information concerning signaling equipment may be found in Signal Book, United States Army.

Signal Corps Manual No. 4, Handbook of Submarine Cables of the United States Signal Corps, 1905 has become obsolete and information relative to laying, operation, and maintenance of long submarine cables is supplied in chapter 11 of this manual.

CHAPTER 1.

THE VOLTAIC CELL, OHM'S LAW, AND PRIMARY AND SECONDARY BATTERIES.

THE VOLTAIC CELL.

If zinc and carbon are immersed in an acid or saline solution and the two connected externally by a wire, an electric current will flow from one to the other. Any two dissimilar metals when immersed in an acid solution which acts on one more than on the other and connected externally by a wire will produce similar results. There are a few nonmetallic substances which if used in a voltaic cell in the place of metal elements will produce the same result. The submerged substances are termed plates or elements, and the solution is termed electrolyte. The combination of plates or elements, electrolyte, and containing vessel constitutes a voltaic cell.

Authorities differ as to just why a current of electricity flows under the conditions stated above. Suffice it to say that it does flow, and that invariably one of the plates is acted upon (decomposed or eaten away) to a very much greater degree than the other. Experiment has shown that substances under above conditions which are acted upon equally do not cause a current of electricity to flow.

Where carbon and zinc are used as the plates in the voltaic cell, the carbon is termed the negative plate or element and the zinc is termed the positive plate or element. The carbon or negative element forms the positive pole of the bat-

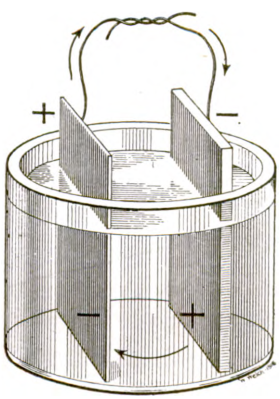

Fig. 1-1.—VOLTAIC CELL.

tery, and the zinc or positive element forms the negative pole. The reason for this apparent contradiction is as follows: In any source of electricity the current flows from positive to negative, and in the voltaic cell, with plates connected externally with a wire, the current flows from zinc through electrolyte to carbon; this is termed the internal circuit. Outside the battery current flows from carbon plate through wire to zinc; this is termed the external circuit. Thus it will be noted that in the internal circuit the current flows to and from directly opposite plates to those in the external circuit. Figure 1–1 illustrates the above.

The term "circuit" is applied to the entire path through which the current of electricity flows. The wire joining the plates is a conductor. Bringing the ends of the conductor into contact is called making or closing the circuit, and their separation, opening or breaking the circuit. A substance through which the current readily flows is a good conductor. Any substance which offers an extremely high resistance to the flow of an electric current is an insulator. Most metals are good conductors, while mica, glass, porcelain, dry wood, dry atmosphere, rubber, etc., are insulators.

OHM'S LAW.

With any circuit through which a direct current of electricity is flowing there are the three governing factors, which are as follows:

(1) The difference of potential between the positive and negative pole of the generating medium, known as the pressure or electromotive force, the unit of which is the volt. (Abbreviated V., E., or E. M. F.) One volt is that electromotive force which would maintain in a circuit having 1 ohm resistance a current strength of 1 ampere.

(2) The resistance or opposition by the conductor to the flow of current, the unit of which is the ohm. (Abbreviated R.) One ohm is that resistance in a circuit which if impressed with an electromotive force of 1 volt allows a current strength of 1 ampere to flow through the circuit. One ohm is the resistance of a column of mercury about 42 inches high and 0.00155 square inch in cross-sectional area at zero centigrade.

(3) The current strength or rate of flow, the unit of which is the ampere. (Abbreviated I.) One ampere is that strength of current which would be maintained in a circuit having 1 ohm resistance if impressed with an electromotive force of 1 volt.

From the above it will be noted that a definite relation exists between these factors, so that the value of any one of them can be found if the values of the other two are known. This relation, expressed by Ohm's law, is as follows:

(*a*) The current strength in a circuit may be found by dividing the pressure, or electromotive force, applied to it by the resistance.

$$I\text{ (in amperes)}=\frac{\text{E M F (in volts)}}{\text{R (in ohms)}}.$$

(*b*) The electromotive force, or pressure, required to maintain a certain current strength in a circuit may be found by multiplying the current in amperes by the resistance in ohms.

(*c*) The resistance in any circuit may be found by dividing the electromotive force by the current strength.

$$\text{R (in ohms)}=\frac{\text{E M F (in volts)}}{I\text{ (in amperes)}}.$$

When the total electromotive force is used in Ohm's law, the total resistance must be used to calculate the current strength. For example, if a coil of 0.5 ohm resistance is connected to a cell of 2 volts E. M. F., the current through the coil would not be $\frac{E}{R}$ or $\frac{2}{0.5}=4$ amperes as might be supposed. It requires a certain part of the cell's E. M. F. to force the current through the internal circuit; therefore, the internal and external resistances must always be added together and divided into the total E.M.F. to find the current flowing. Now, if the internal resistance of the above cell were 0.5 ohm, the total resistance would be 0.5+0.5=1 ohm and $I=\frac{E}{R}=\frac{2}{1}=2$ amperes, or half of the first result.

Ohm's law applies also to any part of a circuit the same as to the whole circuit. When applied to part of a circuit care must be taken to use only the E. M. F., resistance, and current strength of that portion of a circuit considered. Therefore, when E is used as total E. M. F., R must be the total resistance, and when E is used as the pressure applied to part of a circuit, R to correspond must be the resistance of that part of the circuit to which the E was applied. This application of the law may be illustrated by the following problem:

The E. M. F. of a cell is 2 volts; its internal resistance 0.5 ohm. It is connected to three spools of wire in series. By measurement we find that the E causing the current to flow through one of the spools, of which the R=0.4 ohm, is 0.6 volt. What current is flowing through this spool?

By Ohm's law $I=\frac{E}{R}=\frac{0.6}{0.4}=1.5$ amperes.

Now, since the current is the same in all parts of a series circuit, 1.5 amperes flow through each of the spools and also through the internal resistance. This also illustrates the difference between the E. M. F. and potential difference. The difference of potential or pressure between the ends of the spool is 0.6 volt, while the E. M. F. of the cell is 2 volts.

What part of the total E. M. F. is used in overcoming the internal resistance of the cell in the above problem?

By Ohm's law $E=I\times R=1.5\times 0.5=0.75$ volt.

This gives pressure lost or "volts drop" inside the cell.

The resistance of any conductor increases with its length and decreases with area of cross section and for most conductors the resistance increases with rise of temperature.

Electric current so far discussed in this manual has been direct or unidirectional as appertaining to its flow in a circuit and is termed "direct current." (Abbreviated D. C.) This current may be so treated that it will become either alternating or pulsating in character. When this occurs Ohm's law still applies, but there are other factors that must be considered in computing values of I., E. M. F., or R.

With an alternating current (abbreviated A. C.) the flow in a circuit is continually reversing in direction. Certain types of generators produce alternating currents which change direction periodically and uniformly, the speed of rotation of the rotor of such generators being constant. Such currents are expressed in number of cycles per second, 60 cycles being the most commonly used for commercial electric lighting and power systems. Two alternations (change of direction) are contained in a cycle.

Unlike this current, the alternating current produced in telephonic communication is not periodically uniform nor is the E. M. F. in any way constant. The E. M. F. of these alternating currents is usually extremely high and the current strength very low, consequently the source of the current for transmitting the voice waves from a single instrument need only be capable of producing a comparatively weak current strength. For this reason a person coming into contact with both sides of a talking circuit will not be injured by the talking current.

A pulsating current is one which varies in magnitude. As ordinarily employed the term refers to unidirectional current. A pulsating current may also be formed by superimposing upon a direct current an alternating current. When the alternating current is flowing in the same direction as the direct current the former accentuates the latter, and when flowing in the reverse direction it counteracts, in a degree, the direct current.

These currents will be encountered in the study of the operation of the telephone and similar apparatus. In chapter 2 of this manual explanation is made of how they are produced.

Standard Batteries Supplied by the Signal Corps.

There are two classes of batteries, viz, primary and secondary, the latter being sometimes known as storage batteries or accumulators.

Primary batteries are divided into two classes, known as open-circuit and closed-circuit, and while there is a great variety of each class, the basic principle employed is the same.

Open-circuit cells are used for intermittent service where current is required for only short intervals of time, such as in operating electic bells. Open-circuit cells kept in continuous service for some time become polarized or completely exhausted but will recuperate to a considerable degree on open circuit.

The dry battery is an excellent example of the open-circuit type.

Closed-circuit cells are adapted for supplying current continuously until the energy of the chemical is nearly expended.

This is the form of primary cell most extensively used in telegraphy, where a small but constant current is required.

While formerly the Signal Corps issued several different kinds of open-circuit primary battery cells, such as the Laclanche, Gonda, and the Sampson, all of which employed carbon and zinc for elements, salammoniac dissolved in water as electrolyte and a containing jar of glass, experience has shown that the dry-cell type of primary battery is most satisfactory, and consequently this type forms the standard issue of the Signal Corps.

While all dry cells of this type conform in general with the following description, it is found that different makes vary in efficiency. In order to ascertain the comparative merits of each make, a careful life test is periodically made in the Signal Corps laboratory, Washington, D. C.

The dry battery is a form of sal-ammoniac battery in which the zinc plate constitutes both the containing vessel and negative pole, thereby doing away with the breakable glass jar. An absorbent porous material with a depolarizing mixture around it fills the space between the carbon in the center and the zinc vessel. This porous material is saturated with a solution containing chloride of zinc and sal ammoniac. The top of the cell is sealed with asphalt or similar material. Binding posts for zinc and carbon elements, and pasteboard cover to prevent short circuiting with adjacent cells, complete this form of battery. These cells when carefully manufactured and properly stored are reliable. The cell can not be renewed, but their low cost and the convenience afforded by nature of the construction makes them superior to the wet cell for general use. When these cells are exhausted, a short period of usefulness may be obtained from them in the following manner: Punch a number of holes through the zinc containing case and place them in jars containing a solution of sal ammoniac and water. Salt solution for this purpose may be used but it is not as effective as the sal ammoniac.

The standard sizes of the dry cell are shown in figure 1–2, but it is pointed out that only two of these sizes are in general use with post telephone systems and with instruments used in the field.

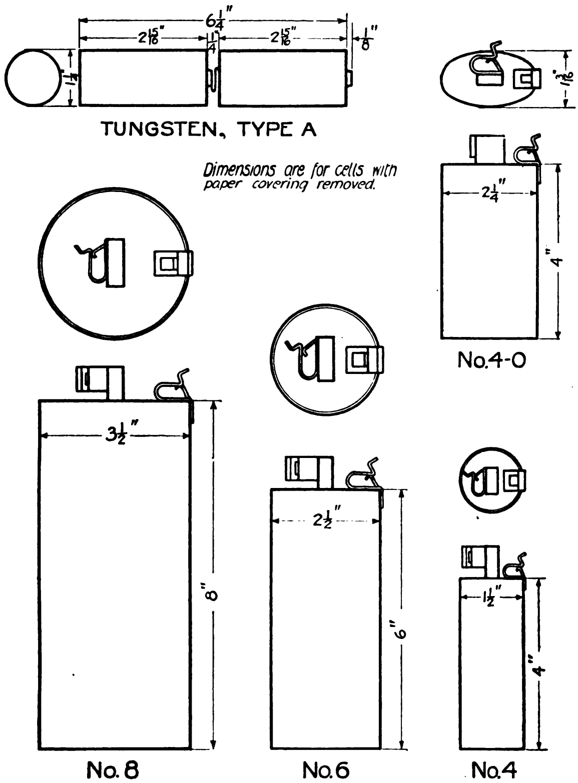

Fig. 1–2.—BATTERY, DRY CELLS, STANDARD SIZES.

Size No. 6, figure 1–2, is invariably used when a local battery is desired for telephones of post telephone systems.

The tungsten type A battery shown in figure 1–2 is used with the service buzzer, the 1914 induction telegraph set, the camp telephone, radio test buzzer, and the hand flashlight. This type of battery is similar in construction to that described above but in order to obtain a comparatively high voltage with minimum weight and bulk, the cells are of small diameter and two cells are so placed in a rigid paper tube that they are connected in series. This combination gives a total voltage of 3—1½ being normal voltage of each cell.

RESERVE TYPE DRY CELL.

The ordinary type of dry cell deteriorates if kept long in storage, even though not in use. To provide a type of dry cell which could be kept in storage without deterioration, the Signal Corps issues a dry cell known as the "reserve type," shown in figure 1–3. This cell, although containing all the elements and ingredients of an ordinary dry cell, does not become active until water has been poured into a cavity of the carbon element. To place the cell in service, remove the plug from the top of the carbon element and fill with water (rain water preferred). As soon as this is absorbed, fill again, until the following amounts of water have been added: Type 4–0, $1\frac{1}{4}$ ounces; type 5, $2\frac{1}{2}$ ounces; type 6, $3\frac{1}{2}$ ounces; after which no more water should be added to these dry batteries.

Great care should be exercised in pouring the water, in order to avoid wetting the cardboard cover. If no funnel is available it is advisable to remove cardboard container during filling. When the cell becomes weak through use, a little sal-ammoniac solution placed inside the carbon element will rejuvenate it to some extent.

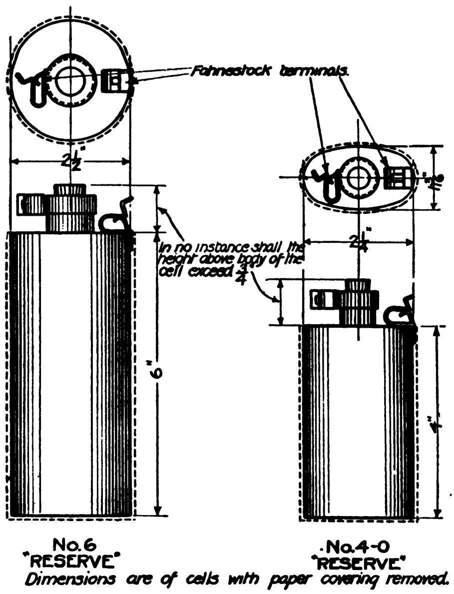

Fig. 1–3.—BATTERY, RESERVE DRY CELLS, STANDARD SIZES.

Referring to figures 1–2 and 1–3, it will be noted that the two sizes of reserve dry cells correspond in dimensions with cells of similar number not of the reserve type. The reserve type has practically been adopted by the Signal Corps. The No. 5 size is not a standard issue.

The voltage of a cell is important and should in no case be less than one volt, but the internal resistance is of greater importance since the cell which is nearly exhausted may at times show a comparatively high E. M. F.

With an ammeter connected directly to the terminals of a No. 6 cell, new cells should show a reading of at least 15 amperes (some cells will show 24). The voltage reading of a new cell on open circuit should be at least 1.4.

Ammeter readings should be accomplished as quickly as possible, as in making the test the cell is practically short circuited, the ohmic resistance of ammeter being very low.

Ordinarily, dry cells tested in accordance with the above which show a voltage lower than 1 or a reading of ammeter less than 2 should under no circumstances be turned into supply depots or transferred to accountable officers.

The above does not apply to the reserve type of cell unless it has been put in commission by the addition of water.

Dry cells in good condition have a voltage of about 1.45. The internal resistance and weights of the various types are about as follows:

Size.	Internal resistance.	Weight.	Size.	Internal resistance.	Weight.
	Ohms.	*Ounces.*		*Ohms.*	*Ounces.*
4–0	0.25	11¼	8	0.10	80
4	.25	9	Reserve 4–0	.29	11¼
5	.20	18	Reserv 5	.22	18
6	.20	32	Reserve 6	.19	32
7	.12	56	Type A tungsten [1]	.30	8

[1] Internal resistance shown is for each cell of the unit. Weight shown is for the unit complete, including cardboard container.

CLOSED-CIRCUIT BATTERIES.

The gravity, Fuller, and Edison are the types of closed-circuit cells supplied by the Signal Corps.

Useful data on the above cells is shown in the following table:

Type of cell.	Voltage.	Weight.	Internal resistance.
		Pounds.	*Ohms.*
Gravity	1.00	11¾	3.0
Fuller	2.00	12	.2
Edison	.67	11	.07

GRAVITY CELL.

This is the form of primary cell most extensively used in telegraphy and telephony when a small but constant current is required. The usual form is shown in figure 1–4.

These cells have been furnished previously in two sizes, each being designated by dimensions of containing jar. One size is 6 by 8 inches and the other is 5 by 7 inches. The latter size has been recently adopted by the Signal Corps as standard, and this size only will hereafter be issued.

In the bottom of the jar are placed three strips of sheet copper, riveted together, as shown in figure, with a rubber-insulated wire attached to one of the strips. There are many forms of zincs, but the "crowfoot" is the form now almost universally used.

To set up the cell, place about 3 pounds of bluestone (sulphate of copper) in the cell after putting in the copper, then hang the zinc and fill with water. The bluestone should be allowed to settle without any attempt to dissolve it by stirring or other means. The cell or cells are then "short-circuited" (zinc and copper connected together) and allowed to stand several days. By that time part of the bluestone will have dissolved, the blue line being well defined. Above this will be a clear solution of sulphate of zinc, formed by the action of the battery; the sulphate of zinc, being of less specific gravity than the copper sulphate solution, will remain on top if the cell is not shaken or stirred up. The battery may now be put into service.

If in a hurry for the cell, it may be started off at once by stirring up about a tablespoonful of salt with the water before pouring it into the cell; but this method is apt to make a battery dirty and considerably shorten its period of usefulness. Any long, dark masses forming on the lower part of the zinc should be removed with a stick. The zinc sulphate solution will grow stronger and stronger, until finally the white salts will begin to creep or climb up the sides of the jar and the zinc. As they will corrode the connections and cause dirt and loss of insulation around the cells, they should be removed. Much of the trouble will be obviated if, as soon as they appear, part of the zinc sulphate solution is drawn off with a battery syringe or a siphon made of bent-glass tube, and water put in its place. If the upper parts of the cells are

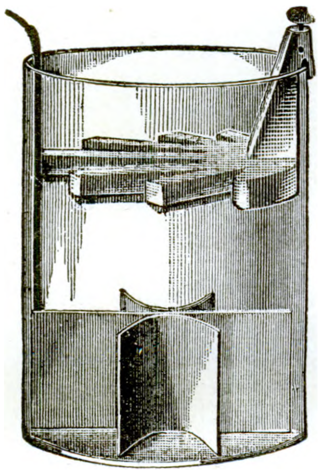

Fig. 1-4.—BATTERY CELL, GRAVITY.

Part No.	Name.	Reference No.
1	Jar, glass	
2	Crowfoot, zinc	
3	Strips, copper with lead	
4	Bluestone, 1 charge (3 pounds)	

warmed and smeared with paraffin it will help matters. But the best plan of preventing evaporation and creeping of salts is to use a good quality of paraffin or lubricating oil, pouring on a layer about one-fourth inch thick as soon as the cells are set up. In cleaning cells after that, wet cotton waste dipped in sand will clean the zincs, etc., of the adhering oil. As soon as the blue solution goes down below the level of the copper more bluestone should be added. Corrosion of the connections of the zincs with their wires should be carefully looked after. It is better to have routine inspections of batteries made, and, if practicable, instrumental tests made with the voltmeters or voltammeters. By this means deterioration may be accurately noted and many annoyances, breakdowns, and delays which are frequently due to neglect and lack of regular inspection of the batteries may be avoided.

The internal resistance of a gravity cell in good condition will be found to be about 3 ohms, its E. M. F. 1 volt.

FULLER BATTERY.

This belongs to the class popularly called "acid batteries." The cell has a high electromotive force, a comparatively low internal resistance (0.5 ohm), and is much used as transmitter battery on long-distance heavily worked telephones or local battery telephone switchboards. Its only disadvantage is that it uses a corrosive solution containing sulphuric acid, necessitating much care in handling. It consists of a glass jar about 8 inches high and 6 inches in diameter, with a wooden cover treated with asphaltum or P. & B. paint. (Fig. 1-5.) This supports a carbon plate about 4 inches wide, 9 inches long, and one-fourth inch thick, with the top coated with paraffin to prevent the cor-

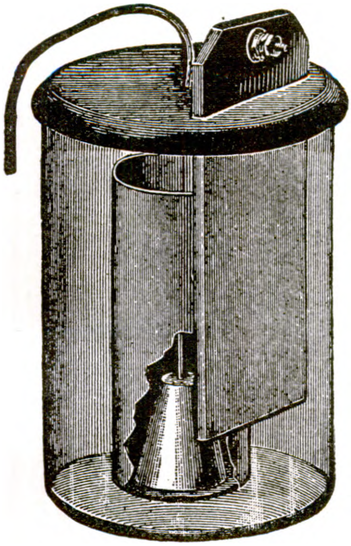

Fig. 1-5.—BATTERY CELL, FULLER.

Part No.	Name.	Reference No.
1	Jar, glass..........	....
2	Cover, wooden with carbon plate..........	....
3	Porous cup..........	....
4	Zinc conical, with wire..........	....
5	Mercury, 2 ounces..........	....
6	Chromac, 1 charge (1 pound)..........	....

rosion of the connection by the acid. In the jar stands an earthenware porous cup 7½ by 3 inches, in the bottom of which is placed about 2 ounces of mercury. In this stands a conical zinc cast to a copper wire which extends out at the top. In the glass jar is placed the "electropoion" solution, made by slowly adding 1 pound of strong sulphuric acid to 9 pounds of distilled water, and then stirring in 3 pounds of pulverized bichromate of potash or 2½ pounds of bichromate of sodium. This last is preferable, as the crystals formed in the action of the cell are not so hard and insoluble as those produced by the potash. In the porous cell with the zinc and mercury is placed water in which about a tablespoonful of salt has been dissolved. This cell will usually require little attention for three or four months. When the solution assumes a muddy bluish tint it is about exhausted.

If the copper wire at its junction with the zinc is covered with paraffin or ozite, or if the copper wire is well amalgamated by rubbing with mercury after dipping it into acid, the wire does not tend to be eaten off at the junction, as it otherwise does under heavy service. The Signal Corps issues the materials for the solution in dry form, which when dissolved form the electrolyte. This is purchased under various commercial names as chromac, voltac, chromite, salts, etc., the first being the usual designation. It is packed in tin cans with thin cut-out top, containing 1 pound, which is the amount for one charge. Full directions for using are marked on each can.

The carbon of this cell lasts indefinitely, but should be soaked in warm water when renewals are made. The zinc may last through several renewals of the electropoion fluid. The mercury should be saved and used repeatedly.

The following table, quoted from Abbott's Telephony, indicates the effect of age on efficiency of transmission with the Fuller cell.

Two-cell Fuller battery.

Age.	Volume of transmission.	Age.	Volume of transmission.
Days.	*Per cent.*	*Days.*	*Per cent.*
20	92	60	76
30	88	70	70
40	84	80	62
50	80	90	54

From this it would appear that the cells must be renewed at least once in three months when used on a telephone transmitter.

EDISON PRIMARY BATTERY.

The type V cell shown in figure 1–6 is the standard Edison cell. As previously manufactured for the Signal Corps, it has the same capacity as the old Edison La Lande cells, but its enameled steel jar was slightly conical, enabling the cells to be nested together for transportation. The caustic soda and oil for each cell are issued in tin cans, so that there is nothing that will not stand transportation. This cell has a very low internal resistance (not exceeding one-eighth ohm) and will remain set up on open circuit for a long time without appreciable depreciation. It has a capacity of about 150 ampere hours, which means that it will furnish about 210 days' continuous service on a line where the current is 30 milliamperes and 40 days' service when the current is about 0.16 ampere.

It gives but 0.67 volt E. M. F. in steady work.

The following complete directions for setting up, management, and renewal of these cells are furnished by the company manufacturing them:

DIRECTIONS FOR SETTING UP AND USING EDISON PRIMARY BATTERY, KNOWN AS EDISON CELL, TYPE V.

TO CHARGE AND CONNECT BATTERIES.

To make solution.—Fill the cells with water to 1½ inches of the top.

Add the caustic soda gradually to the water, stirring until the soda is entirely dissolved.

When the solution cools, more water should be added to bring it up to 1½ inches of the top. Then pour contents of bottle of heavy paraffin oil from bottle furnished for each jar on the solution.

NOTE 1.—The caustic soda will burn the skin and clothes. In stirring the liquid, avoid splashing it.

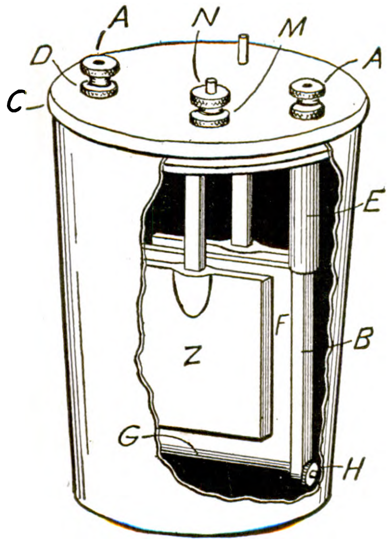

Fig. 1–6.—BATTERY CELL, EDISON PRIMARY TYPE V.

Part No.	Name.	Reference letters.
1	Jar, enameled steel	
2	Cover for jar	C.
3	Plate, oxide	F.
4	Copper bolt	G.
5	Copper nut	H.
6	Thumb nut	N, A.
7	Jamb nut	M, D.
8	Double zinc plate	Z.
9	Leather washer	
10	Insulating tubes, hard rubber	E.
11	Frame	B.

To set up cells.—Unscrew the nut *N* and the jamb nut *M* from the screw on the brass neck of the double zinc plate and remove the leather washer. Pass the screw from below through the central hole in the cover *C*. Replace the leather washer and the jamb nut *M* on the screw and tighten down the jamb nut until the zinc plate is rigid to the cover. The thumb nut *N* can then be screwed on.

Unscrew the nuts *A A* and jamb nut *D* from the screws on the two side pieces *B B* of the copper frame, leaving the flat leather washers in position on the screws, and pass the screws from below through the two round holes in the cover *C*. Replace the jamb nut on one of the screws and one of the thumb nuts on the other screw, and tighten both down until the frame sides are rigidly clamped to the cover. Replace the other thumb nut on the screw holding jamb nut. Then slip the hard rubber insulating tubes *E E* over the sides of the frame, one on each side.

To fill copper frames.—(In this cell only one oxide plate is used.) (See fig. 1–6.) Slide the oxide plate *F* sufficiently far into the frame to enable the copper bolt *G* to be passed underneath it through the slots in the bottom of the frame sides and the copper nut *H* tightened up on same.

Be careful that the zinc plates do not touch the copper oxide plates or the cell will be short-circuited.

The copper connection is made between the thumb nut *A* and the jamb nut *D* on one end of the copper frame and the zinc connection between the thumb nut *N* and the jamb nut *M* on the brass bolts suspending the zincs.

After the oxide and zinc plates are properly connected to the cover, as above, soak them in water and while still wet insert in jar filled with caustic solution. (Wetting the plates prevents the oil in jar from adhering to them.)

Important.—In order to allow the cover on the jar to fit easily, it is advisable to wet the rubber gasket ring fitting into the grooved edge of the cover by placing it in water. This will cause the cover to slip on easily and will make the cell liquid tight.

It is absolutely necessary that the upper edge of the oxide plates should be submerged at least 1 inch below the surface of the caustic soda solution in the jar; also on no account can the layer of oil on top of the solution be omitted.

RENEWING.

When the cell becomes exhausted the solution and the remains of the zinc and oxide plates must be thrown away. The remaining parts can be used again.

TO TAKE THE CELLS APART.

Lift the lids, unscrew the bolts, and remove the zincs and oxide plates. Wash off (with water) the copper frames, bolts, and rubber insulators, brightening up the metal where corroded with emery paper, especially the inside grooves of the copper frame sides. Pour away the solution carefully and set up cells with new caustic soda, oxide plates, and zincs according to directions.

Note.—In taking the cells apart the parts that have been immersed in the caustic soda must be washed before they are handled.

TO ASCERTAIN IF THE OXIDE PLATES ARE EXHAUSTED.

Pick into the body of the oxide plates with a sharp-pointed knife. If they are red throughout the entire mass, they are completely exhausted and need renewing. If on the contrary, there is a layer of black in the interior of the plate, there is still some life left, the amount being dependent entirely upon the thickness of the layer of black oxide still remaining.

COPPER FRAMES.

When renewing the battery it is desirable to clean the inside grooves of the copper frames, where the copper-oxide plates make contact, so as to insure a good electrical connection. This is especially important where the batteries are required to give a heavy current for cautery or motor purposes. These frames can be easily cleaned by wrapping a small piece of emery paper around a stick which will just fit into the groove, or by immersing them in a dilute solution of 1 part of sulphuric acid and 4 parts water, and then carefully rinsing them in clean water to remove all traces of the acid.

Caution.—The oxide plates should never be removed from the caustic soda solution and allowed to dry in the air, as, if this is done, the surface of the plates becomes oxidized by absorbing the oxygen from the air, and the oxide thus formed is much more difficult of reduction than the original oxide of which the plates are formed. The internal resistance is consequently very greatly increased and the current materially diminished.

Note.—Where batteries are placed in warm places they should be examined every two or three months to see that the solution has not evaporated, as this will gradually take place, in spite of the oil, if they are in a hot room. If the solution is found to have evaporated, add more water to bring it again to the proper height. It is of the first importance that all binding posts and connecting wires should be kept clean and bright at the points of connection.

The type V cell is excellent for use as an ignition battery or in lieu of small capacity storage batteries where no charging current exists. The Signal Corps uses this type of battery quite extensively in connection with the Alaska Military Cable and Telegraph System.

GROUPING OF CELLS.

When it is necessary to cause a certain current to flow through a considerable resistance, as a long telegraph line, for instance, the necessary E. M. F. is obtained by connecting cells in series—that is, the copper of one cell to the zinc of the next, and so on until the requisite E. M. F. is obtained, the relatively small increase of the total resistance due to the internal resistance of the cells being of little effect. The total voltage is the sum of the voltages of all the units so connected. But when it is desired to get a certain current through a low resistance, another grouping must be made. The internal resistance of the ordinary gravity cell is about 3 ohms. And with its one volt E. M. F. the current through a short thick wire of no appreciable resistance connecting its poles will be one-third ampere. And if we have 100

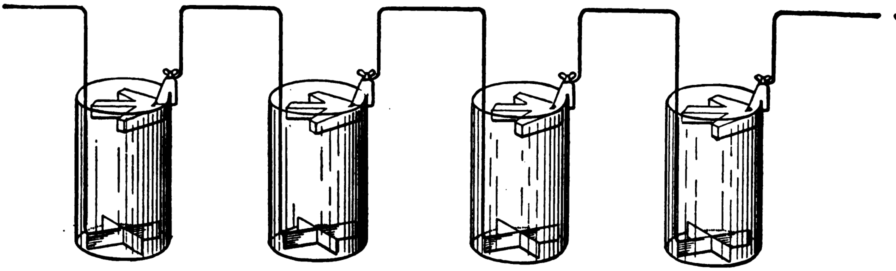

Fig. 1–7.—BATTERY CELLS CONNECTED IN SERIES.

cells in series and connect the terminals of the entire battery, we would get $\frac{100}{300}$ ampere, or one-third, as before. For any number of these cells in series, to obtain an increased current through low external resistance, we must cut down the internal resistance of our battery. This, with a given type of cell, may be done by linking them in parallel—that is, by connecting all the zincs together and all the coppers together and then connecting the multiple zinc and multiple copper thus obtained to the low external resistance. The E. M. F.

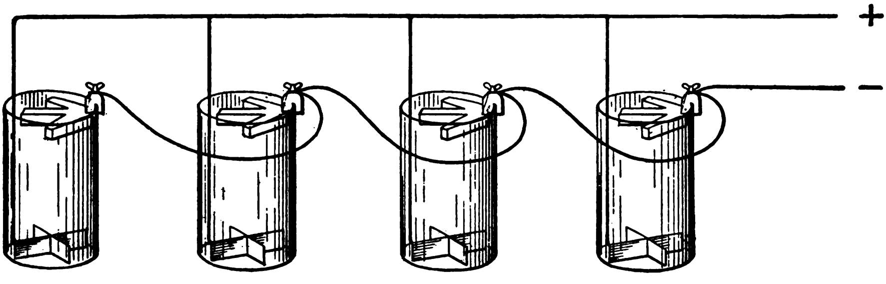

Fig. 1–8.—BATTERY CELLS CONNECTED IN MULTIPLE.

of the battery remains the same as that of one cell, but the current output is now equal to the sum of the current capacities of all the units so connected.

Figure 1–7 shows four cells of battery connected in series and figure 1–8 shows four cells of battery connected in multiple, or parallel as it is sometimes called.

In the first case we should get a current of $\frac{4}{12}=\frac{1}{3}$ ampere through our short circuit; and in the second case, $I=1\div\frac{3}{4}=\frac{4}{3}$ ampere.

While in both figures the gravity cell is shown, the rule is applicable to any type, class, or make of primary or secondary battery cells.

Number and kind of battery cells required by various apparatus.

[Where more than one battery cell is indicated the cells are invariably connected in series.]

Instrument.	Cell.	Number of cells.
L. B. post-telephone switchboard [1]	Gravity	3.
	Fuller	2.
Camp switchboard	No. 6 reserve	2.
L. B. telephone, post-telephone system	do	2.
Camp telephone	Type A tungsten	1 unit (2 cells).
Service buzzer	do	2 units (4 cells).
Induction telegraph set	do	Do.
Test buzzer for radio pack set	do	Do.
Flash-light	do	1 unit (2 cells).

[1] Either gravity or Fuller may be used for operator's transmitter circuit. In addition, 2 cells of No. 6 reserve may be used for night alarm.

Secondary Batteries.

The storage battery differs from the primary battery in its action in that when it has given out all the energy the chemicals present enable it to supply, instead of requiring new elements, the cell can be completely regenerated or brought back to its original charged condition by passing a current into it in a direction opposite to that in which the flow took place on discharge.

Although there are many combinations which can be used for storage batteries, a large majority of those in commercial use and all those installed by the Signal Corps are of the lead-sulphuric acid type, which in its basic principle consists of two especially prepared dissimilar lead plates immersed in diluted sulphuric acid. Each cell of the lead-sulphuric acid storage battery has an E. M. F. of about 2.05.

The Edison storage battery which has recently been developed and placed on the market makes use of oxides of nickel and iron in the positive and negative electrodes respectively. The grids supporting the active material are made of nickel-plated steel, and the electrolyte is a solution of caustic potash and water. These cells when fully charged have a normal E. M. F. of 1.2 volts and are charged at about 1.7 volts. They stand abuse much better than the lead-sulphuric type of battery and are highly advantageous for vehicle purposes, as it is claimed the output per unit of weight is nearly twice that of lead cells. An idea of the ruggedness of this battery can be imagined when consideration is given to the fact that when the battery becomes unhealthy or impaired by lack of work, or too much work, short circuiting the battery for a moderate period will assist in returning the battery to a healthy condition.

Secondary batteries in the form of storage batteries or accumulators are used by the Signal Corps for supplying necessary current in connection with comparatively large telephone systems, signaling systems, and telegraph systems where a suitable charging circuit is available. When used for supplying current for the operation of post telephone systems, the systems are invariably what are termed "common-battery" or "central-energy" systems. With this type of system the current for operation of all apparatus is obtained from one battery. In a local-battery telephone system the switchboard and each telephone is equipped with a battery.

In fire-control systems at seacoast defenses 15 cells of storage battery, connected in series, are installed for supplying current for operation of the telephone system of the fire-control system proper, and in a great many instances the same battery furnishes current necessary in the operation of the entire post telephone system. In emergency the same battery may also be used to supply all signal apparatus of the fire-control system, which normally is supplied by current obtained from a motor generator set, the motor generator set being used to charge the storage battery when operation of the system is not in progress.

Either a battery of 12 cells or a battery of 15 cells of storage battery, connected in series, are installed for supplying necessary current for operation of common-battery post telephone systems at interior posts.

General Data Concerning the Storage Battery.

The elementary form of storage cell is made by immersing two lead plates in dilute sulphuric acid. The principle involved in the storage cell is the chemical action produced by a current which causes such changes of the lead plates in the acid that upon cessation of the current, if the two plates are connected together by a wire, a current will flow in the opposite direction from the original one and the plates will tend to return to their original condition.

The action of the current is to coat the plate that is connected with the positive pole of the charging dynamo with peroxide of lead, and to reduce to spongy metallic condition the surface of the plate connected with the negative pole. When the plates are connected by a wire the peroxide coating tends to be reduced back to lead and the spongy lead on the other plate to become oxidized. The plates thus becoming alike the current will cease and the cell is said to be discharged. Various methods of manufacture are intended to give the plates more capacity; that is, to prepare more reducible peroxide on one and more spongy lead on the other. The means adopted are to make the plates up in the form of fine strips or grids of lead and fill in these interstices with the oxides of lead by various processes. These plates, being made up in sets, are then immersed in acid and given what is called a "forming charge," after which they may be used.

The plates as received from the manufacturer are of two kinds. The sets of plates of one kind are of a chocolate brown, while the other sets are of a grayish leaden color. When these are placed in the jars the sets of plates represent the zinc and copper, respectively, of a primary battery, the gray plates acting as zincs and the brown as copper. In connecting cells in series the brown set of one cell should be connected with the gray set of another, and so on. Care should be taken that no plates of different kinds touch on the inside of cells, and that the separators are properly placed, if these are furnished with the kind of cell used. The connecting lugs should all be brightened before they are bolted together, and after all connections are made it is well to go over them with a coating of cosmoline or asphaltum varnish. The cells should always be set up in a dry place, preferably where there is a good means of lighting and where there may be ample ventilation.

The first or initial charge of any storage battery takes a much greater length of time than the subsequent regular charges. The initial charge of any make of storage battery should be continuous if possible. With most batteries it takes from 50 to 60 hours to complete the initial charge, while the regular charge thereafter should be completed in approximately eight hours at the normal rate. The battery should not be discharged below 1.70 volts per cell.

Purity of electrolyte is of first importance in storage battery operation, and all acid should be tested where a doubt as to its purity exists.

TESTS FOR PURITY OF ELECTROLYTE.

The necessity for using pure electrolyte in storage batteries is something which is seldom recognized. Its importance in maintaining a battery in its highest efficiency for any length of time is a matter which should receive attention, not only at the time the battery is set up but subsequently, in the addition of water or fresh electrolyte.

The most frequent impurities in water are sodium or magnesium chloride, and some of the salts of lime and iron. The presence of lime will of course be objectionable, but its presence in very small quantities is less objectionable than that of the other impurities.

In general, it may be stated that the only suitable water for safety is distilled water, and no amount of trouble necessary to get this kind of water should be considered as too great when making up the electrolyte if strong acid be furnished, or for subsequent additions to replace loss by evaporation.

Of course all dry reagents should be dissolved only in distilled water in preparing for tests. Unless otherwise stated, the testing solutions should be about one-half saturated.

If strong acid is furnished, the method of mixing this with the requisite amount of water to bring the specific gravity of the solution to 1.210, is stated later. It is urged that no acid be used which is made from iron pyrites; the only suitable electrolyte is made from acid which is manufactured from pure sulphur.

The impurities which may be in the acid, and for which tests should be made, are: Chlorides or free chlorine, the salts of iron, copper, mercury, and the nitrates. Small cases of reagents may be furnished by the Signal Corps for storage-battery installations where there are 15 cells and upward, and tests should be made before setting up the battery and in subsequent additions of electrolyte if a doubt as to its purity exists.

It must be noted that after running some time the electrolyte may become contaminated with chlorides or nitrates from the plates, formed during manufacture.

The small reagent case (fig. 1–9) is furnished for testing electrolyte. The contents of this case are shown in the parts list of the illustration.

If distilled water is used, of course no tests of it will be necessary, but any natural water should be open to suspicion.

Tests for chlorine or chlorides.—A few drops of solution of nitrate of silver in a test tube partly filled with electrolyte will give a curdy, white precipitate of silver chloride if chlorine or its salts are present. This chloride turns to a violet tint on exposure to light. If the clear liquid be poured off and strong ammonia added to the white precipitate, it will dissolve.

Test for iron.—The presence of ferrous salts in the electrolyte is shown if a dark-blue precipitate is given upon the addition of a solution of the red prussiate of potassium. If ferric salts are present in the electrolyte, a solution of yellow prussiate of potassium will give a blue tint. Consequently, if into two test tubes, one of which contains a few drops of yellow prussiate and the other a few drops of red prussiate, a little electrolyte be poured, the two tests can be made at once. If the impurities be present in small quantities there will not be a precipitate formed, but a bluish-green coloration will result.

Test for copper.—Place a small quantity of electrolyte in a test tube and add an excess of strong ammonia. If copper be present there will be a bright bluish tint given to the mixture. If present in large quantities, a chocolate-colored substance will be formed upon the addition of a solution of the yellow prussiate of potassium.

Test for mercury.—The mercurous salts will give an olive-green precipitate with iodide of potassium; the mercuric salts, a scarlet precipitate with the same reagent.

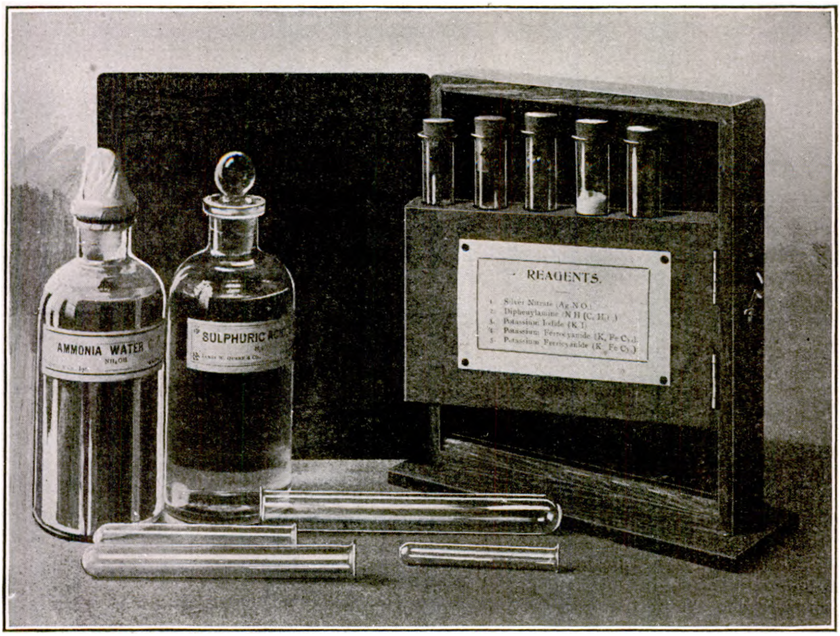

Fig. 1-9.—CASE, REAGENT.

Part No.	Name.	Reference No.
1	Acid, sulphuric, 8 ounces	
2	Aqua ammonia, 8 ounces	
3	Bottles, stoppered, glass	
4	Case, wooden	
5	Diphenylamine, ½ ounce	
6	Iodide of potassium, ½ ounce	
7	Prussiate of potash, red, ½ ounce	
8	Prussiate of potash, yellow, ½ ounce	
9	Silver nitrate, ½ ounce	
10	Tubes, reagent, stoppered	
11	Tubes, testing, 4	

The use of hydrometers having mercury in the lower bulb will frequently give a mercury impurity in the electrolyte through breakage of this bulb. Consequently it is better to use only a shot-filled hydrometer.

Test for nitrates.—Some hiphenylamine should be dissolved in a small quantity of concentrated, chemically pure, sulphuric acid and put in a test tube. A small quantity of electrolyte is then carefully dropped in the same tube. If a blue color results, nitrates or nitrites are present. Traces of nitrates are very objectionable. They cause a surprisingly rapid deterioration of the plates.

The following instructions relative to installing and initial charge of storage batteries is furnished by the Electric Storage Battery Co., of Philadelphia:

UNPACKING AND CARE OF MATERIAL.

1. Great care should be taken in the unpacking and subsequent handling of the various parts of the battery, as many of them are easily broken or bent out of shape by rough handling.

2. Open the crates or packing boxes on the side marked "Up" and carefully lift out the contents; never slide out by turning crate on its side.

3. As the contents of each box or crate is removed, carefully count the parts and check with the shipping list. A number of small parts will usually be found in each shipment, and care should be taken to examine packing to make sure that no parts have been overlooked. All material should be carefully examined for breakage. Cracked or broken jars must not be installed. No claim for damage in transit will be considered and no claim for shortage will be adjusted unless accompanied by a memorandum showing the number of case or package, as a record of all cases by number is carefully preserved by the company, showing the exact contents of all packages, the contents having been double-checked before shipment.

4. The wood separators (sheets and dowels) which have been given a special treatment are shipped wet, and they should be kept so until installed in the battery, and not allowed to dry under any circumstances. If there is any delay in setting up the battery, the sheets and dowels should be left in the packing cases and kept wet by being frequently sprinkled with water at least once a week, the lid of the case being removed while sprinkling. If a supply is to be kept on hand for any length of time, they should be kept completely immersed in a vessel of water to which electrolyte of 1.210 specific gravity has been added in the proportion, by volume, of one part of electrolyte to nine or ten parts of water. The vessel (which must not be of metal) should be covered to keep out impurities.

ELECTROLYTE.

5. The electrolyte shipped with a battery is dilute sulphuric acid of a specific gravity of 1.210 or 25° Baumé (except for type D cells, see note) as shown on the hydrometer at a temperature of 70° F. If it is not convenient to procure the electrolyte from the Electric Storage Battery Co., already mixed and ready for use, it may be prepared by diluting sulphuric acid of 1.840 specific gravity or 66° Baumé (oil or vitriol), which has been made especially for storage battery use, with pure water (preferably distilled) in the proportion of one part acid to four and one-third of water by volume; 1.400 specific gravity acid may be reduced to 1.210 specific gravity by mixing equal volumes of the acid and pure water. It is absolutely essential that both the acid and water should be practically free from impurities such as iron, nitric or hydrochloric acid. When mixing, slowly pour the acid into the water (not the water into the acid) and thoroughly stir with a wooden paddle. The final specific gravity must be read when the solution is cool. A metal vessel must not be used for mixing or handling the solution; a glazed or earthenware crock or a lead-lined tank is suitable, or a wooden vessel which has not been used for any other purpose, such as a new washtub, can be used for mixing, but not for storing the electrolyte. The electrolyte must be cool when poured into the cells.

NOTE.—For type D cells (full number of plates installed), when being first put into commission, electrolyte of 1.180 specific gravity or 22° Baumé must be used. If the electrolyte is to be mixed on the ground, the proportions of acid (of 1.840 specific gravity) and water are one part acid to five and one-quarter of water, by volume. During the initial charge the gravity will rise to about 1.210 (the standard gravity). For type D cells (less than full number of plates installed) electrolyte of 1.210 specific gravity should be used.

LOCATION OF BATTERY.

6. The proper location is important. It should preferably be in a separate room, which should be well ventilated, dry, and of moderate temperature.

7. The ventilation should be free, not only to insure dryness (in a damp room leakage from grounding is liable to develop, but to prevent chance of an explosion, as the gases given off during charge form an explosive mixture if confined. For this reason never bring an exposed flame near the battery when it is gassing.

8. To obtain the best results, the room temperature should be between 50° and 80° F. If the temperature is very high, that is, over 80° F., for any great length of time, the wear on the plates is excessive. If the temperature is low, no harm results, but the available capacity is reduced during the period of low temperature.

INSTALLING BATTERY.

9. Before assembling the cells, suitable racks or stands should be provided and so located in the room that each cell will be easily accessible.

10. Place the jars in the trays, which should previously be filled evenly with the top with fine dry bar sand. Place the elements as they come from the packing cases on a convenient stand or table (the elements are packed positive and negative groups together, the positive group having plates of a brownish color and the negative of a light gray; also the negative group always has one more plate than the positive group). Scrape both sides of the lug at the bolt hole to insure good contact when the cells are connected together. Cut the binding strings and carefully pull the positive and negative groups apart. Remove any loose or foreign matter and place the negative group crosswise on a strip of webbing; then slip the plates of the positive group between those of the negative group, so that the vertical edges of all the plates will be flush. (See fig. 1–D.) The spacing sticks should then be inserted, as shown in figure 1–D, in order to keep the plates apart while lifting.

11. Lift the element by the webbing and lower very carefully into the jar (fig. 1–E), withdrawing the webbing and spacing sticks when the element is properly in place. Be sure that the hanging lugs rest evenly on the sides of the jar. Lift the cell, together with the sand tray, into position on the rack, leaving an air gap of one-half inch between trays. Be careful that the direction of the lugs is relatively the same in each case, thus bringing the positive lug and the negative lug of adjacent cells together. This insures the proper polarity throughout the battery, bringing a positive lug at one free end and a negative at the other. If cells are connected with wrong polarity, the plates will be seriously injured. If wood sand trays (fig. 1–F) are used, put the glass insulators in place by first raising one end of the tray and then the other end, the insulators being so located under the tray that they will be directly under the corners of the jar. Glass sand trays (fig. 1–E) have projections, or feet, on the bottom, and therefore do not require insulators.

12. When all the cells are in position bolt the lugs together, first applying vaseline or grease to the bolt studs. The nuts should be gone over and tightened several times after the lugs are first fastened together, to insure thoroughly good connection. At this time the connections with the charging source (which must be available for charging) must be made ready.

13. The wood separators can now be installed. Remove from packing case or water bath only sufficient sheets and dowels for equipping a few cells at a time. The dowels must always be placed on the sheets at right angles with—that is, across—the grain of the wood. The separators, when equipped with the dowels, should be inserted from the top (see fig. 1–F), one between each plate of the element, the long, solid pointed end of the dowels in every case being downward. Immediately after an element has been equipped with its separators the cells should be filled with electrolyte to one-half to three-quarters inch above the top of the plates. An element with the separators in place must not be exposed to the air any longer than is absolutely necessary. When the electrolyte is in all the cells, place the glass hold-downs in position on the separators, across the middle of the cell, and at right angles with the plates.

CONNECTING UP THE CHARGING CIRCUIT.

14. Direct current only must be used for charging. If alternating current alone is available, a current rectifier must be used for obtaining direct current. In connecting the battery for charging, the positive pole of the charging source must be connected to the positive end of the battery, and likewise the negative of the charging source to the negative of the battery. If a voltmeter is not at hand, the polarity may be determined by dipping two wires from the charging terminal into a glass of water to which a teaspoonful of table salt has been added, care being taken to keep the ends at least 1 inch apart to avoid danger of short circuits. Fine bubbles of gas will be given off from the negative pole.

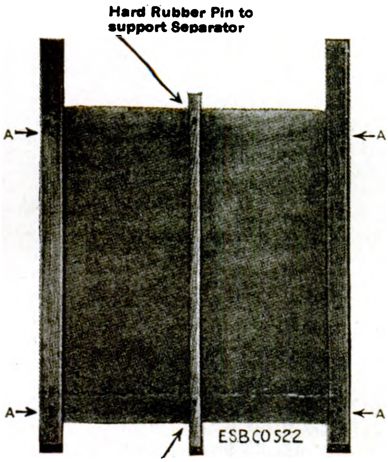

Fig. 1–A.
Assembly of Type F separator.
(See par. 13.)

Fig. 1–Ɔ.
Middle dowel (showing support pin).

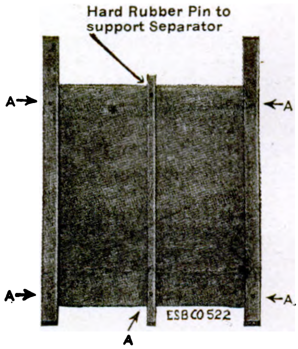

Fig. 1–C.
Assembly of Type D and E separators.
(See par. 13.)

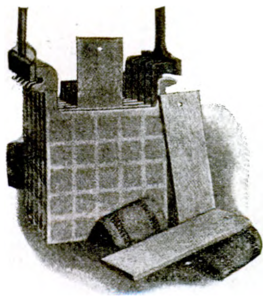

Fig. 1–D.
(See par. 10.)

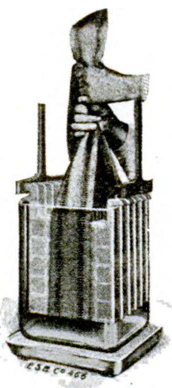

Fig. 1–E.
(See par. 11.)

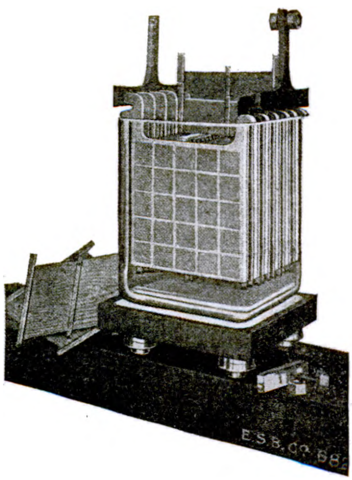

Fig. 1–F.
(See pars. 11 and 13.)

ASSEMBLY OF STORAGE BATTERY PARTS.

Table of ratings.

Type	D.						E.						F.			
Size of plates (not including lugs)	6 by 6 inches.						7¾ by 7¾ inches.						11 by 10½ inches.			
Number of plates per cell	3	5	7	9	11	13	5	7	9	11	13	15	9	11	13	15
Normal rate (amperes), charge and discharge	2½	5	7½	10	12½	15	10	15	20	25	30	35	40	50	60	70
Maximum charge rate (amperes)	3½	7	10½	14	17½	21	14	21	28	35	42	49	56	70	84	98
Range in specific gravity (approximate) for complete discharge [1]	12	18	25	20	30	25	22	30	33	37	40	42	30	32	42	45

[1] For example: If the specific gravity of a type E7 cell is 1.207 when fully charged, it will be completely discharged when the gravity has fallen about 30 points (0.030 specific gravity), i. e., to about 1.177 specific gravity.

INITIAL CHARGE.

[See table of rating.]

16. The charge should be started at the normal rate as soon as practicable after all the cells are filled with electrolyte and all the connections made, and continued at the same rate until both the specific gravity and voltage show no rise over period of 10 hours, and gas is being freely given off from all the plates. The positive plates will gas sometimes before the negative plates. To meet these conditions, from 50 to 60 hours' charging at the normal rate will be required; if the rate is less, the time required will be proportionately increased. In case the charge is interrupted, particularly during its earlier stages, or if it is not started as soon as the electrolyte is in the cells, the total charge required (in ampere hours) will be greater than if the charge is continuous and started at once. As a guide in following the progress of the charge, readings of the current, specific gravity, and voltage should be regularly taken and recorded. The gassing should also be watched, and if any cells are not gassing, or are not gassing as much as the surrounding cells, they should be carefully examined and the cause of the trouble removed. The temperature of the electrolyte should be closely watched, and if it approaches 100° F. the charging rate must be reduced, or the charge temporarily stopped until the temperature lowers. The specific gravity will fall after the electrolyte is added to the cell and will then greatly rise as the charge progresses until it is up to the 1.210 or thereabout. The voltage of each cell at the end of charge will be between 2.50 and 2.70 volts, and for this reason a fixed or definite voltage should not be aimed for. If the specific gravity of any of the cells at the completion of the charge is below 1.205, or above 1.215, allowance being made for the temperature corrections (see below), it should be adjusted to within these limits, adding electrolyte if low, and replacing some of the electrolyte in the cell with water if high, keeping the surface at the proper height (one-half to three-fourths inch) above the top of the plates.

TEMPERATURE.

17. As the temperature affects the gravity, this must be considered and corrections made as follows: To correct to normal temperature (70° F.) subtract one point (0.001 specific gravity) for each 3° F. below 70° and add one point for each 3° F. above 70°. For instance, electrolyte, which is 1.213 at 61° and 1.207 at 79°, will be 1.210 at 70°. It is of the utmost importance that the initial charge be completed in every respect. If there is any doubt, it is better to charge too long than risk injury to plates by stopping the initial charge before it is complete.

While the preceding directions may be applied to any make of storage battery, different manufacturers recommend slightly different methods of procedure in the initial charge of their batteries, which should be carefully followed, as this is the only means by which they can be held responsible for the conduct of their cells, which may be sold on guaranties.

INITIAL CHARGES FOR DIFFERENT MAKES OF CELLS.

For a "chloride" battery the charge should be started at the normal rate as soon as the electrolyte is in the cells (covering the plates about three-fourths inch), and continued at the same rate until both the specific gravity and voltage show no rise over a period of 10 hours and all the plates are gassing freely. Electrolyte of 1.170 specific gravity is furnished for the type BT, CT, PT, and D cells and of 1.210 specific gravity for all the other larger types. The positive plates will gas some time before the negatives. To meet these conditions, from 50 to 60 hours continuous charging at the normal rate will be required for the larger cells, while the types BT, CT, PT, and ET require from 30 to 40 hours for the initial charge; and if the rate is less, the time required will be proportionately increased. In case the charge is interrupted, particularly during its earlier stages, or if it is not started as soon as the electrolyte is in the cells, the total charge required (in ampere hours) will be greater than if the charge is continuous and started at once.

For this operation the Willard Storage Battery Co. recommends as follows:

The charge must be commenced immediately upon filling the cells with electrolyte of 1.200 specific gravity. The battery should be charged at a rate equal to two-thirds of its normal or eight-hour charging rate. The charging should

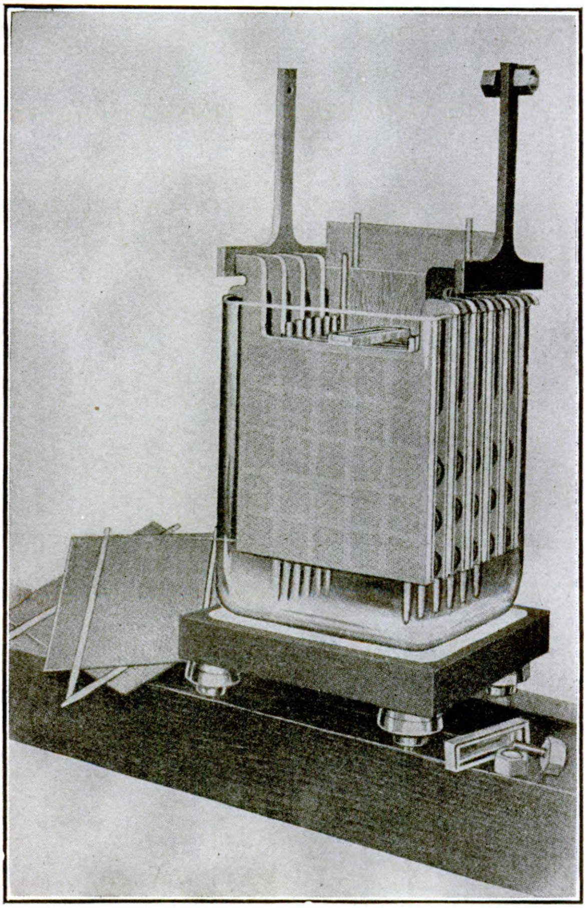

Fig. 1–10.—BATTERY, STORAGE, CHLORIDE.

be continued until the voltage of each cell is 2.6 volts, the reading being taken while the battery is being charged at the above rate. After the cells have reached the voltage named above, or higher, the charge should be continued until the specific gravity of each cell ceases to rise, or has remained constant for at least three hours. This will usually happen after a battery has been charged for approximately 60 hours. The experience of the Signal Corps has been that a longer period of charge is required. If any cells do not show the proper rise in voltage, or do not gas freely, they should be examined. Care should be taken that there are no internal short circuits. If there are they should be removed at once and the charge continued until the cells indicate as above.

The Gould Storage Battery Co. recommends the following procedure for the initial charge of their batteries:

Fill the cells with the electrolyte furnished which has a specific gravity of 1.210. Commence initial charge at twice the normal or eight-hour rate and continue for 12 hours, then reduce to 1.4 times the normal charge rate for 20 hours, then decrease to the normal or eight-hour rate and charge for 20 hours. The specific gravity should be about 1.210 (corrected to temperature) at the end of charge.

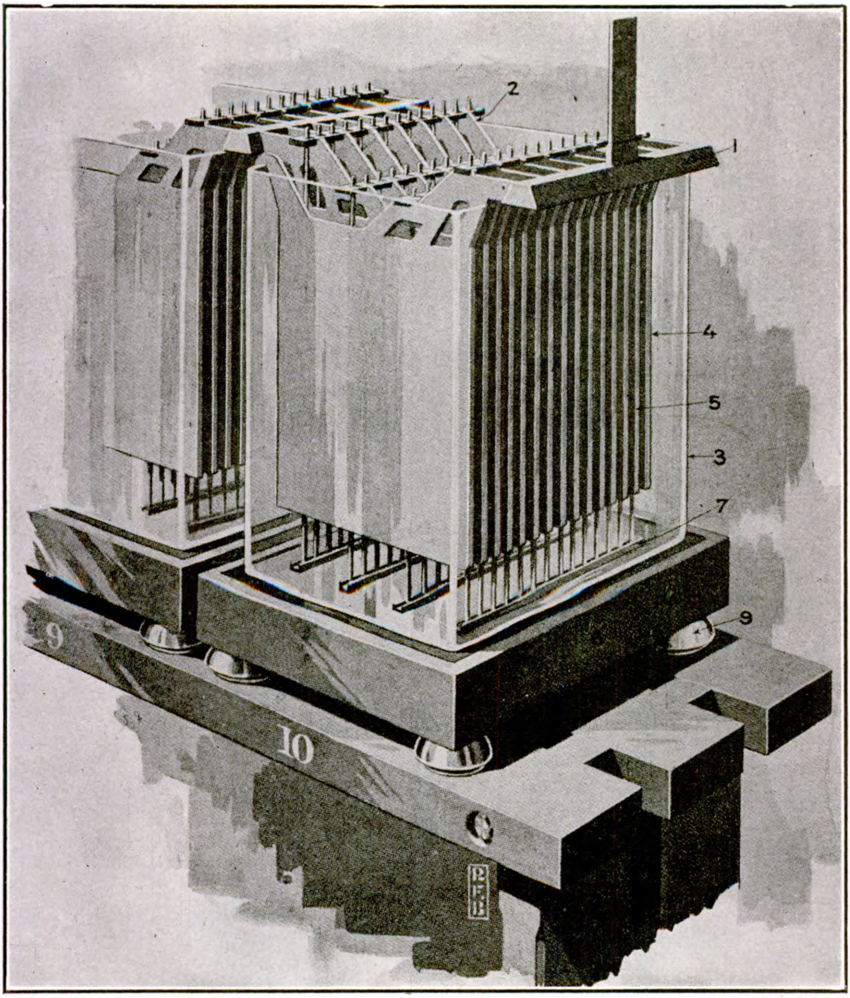

Fig. 1-11.—BATTERY, STORAGE, WILLARD.

In later paragraphs on the maintenance of storage batteries emphasis is laid on the fact that storage batteries should not be allowed to remain in a discharged state. This is because lead oxide immersed in sulphuric acid will be chemically attacked, independent of any current flow, and change into lead sulphate, so that discharged plates tend to take on a coating of lead sulphate, a nonconductor, impairing the efficiency of the cell as an accumulator.

Various methods of manufacture are used to give the plates more current capacity—that is, to expose more reducible peroxide of lead in the positive and spongy lead in the negative plate to the action of the electrolyte. The various methods of manufacture consist in changing the form of the grids and different methods of filling them with the oxides and spongy pure lead. Inasmuch as neither of these have any mechanical strength in themselves, the grids or frames are necessary to make up a suitable electrode.

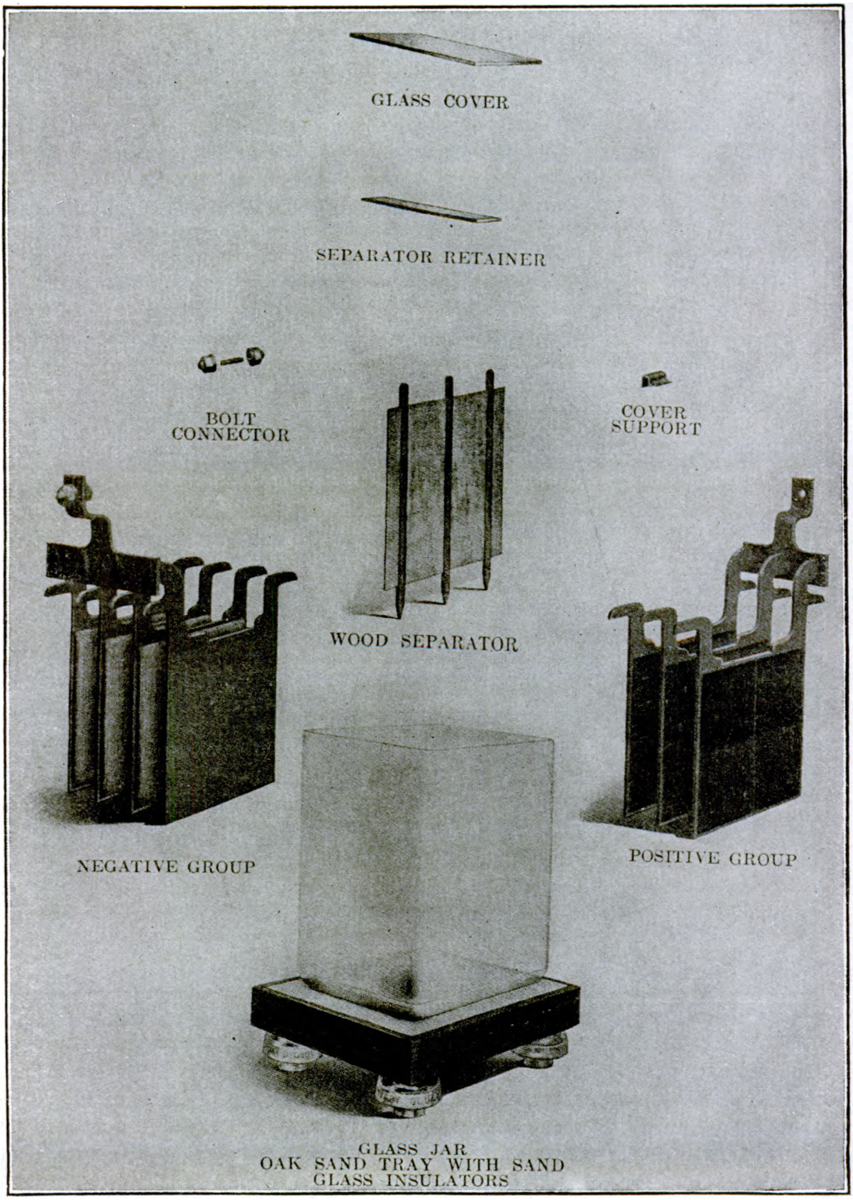

Fig. 1-12.—BATTERY, STORAGE, GOULD.

Different makes of storage batteries are used by the Signal Corps, but to date practically all those used are of the lead types, made by the Electric Storage Battery Co., known as the "Chloride" battery; those made by the Willard Storage Battery Co. and known as the "Willard;" and those made by the Gould Storage Battery Co., known as the "Gould" batteries. (See figs. 1–10, 1–11, 1–12.)

TABLE OF RATINGS.

The ampere-hour capacity and sizes of batteries can be determined by the table herewith, covering all the makes and types of storage batteries used by the Signal Corps.

To determine the normal charge and discharge rates of a battery multiply the "amperes per positive plate" for the particular type in question by the number of positive plates per cell; thus for a type F battery of 13 plates per cell (6 positive and 7 negatives) the normal rate is 60 amperes.

Size of plates, not including lugs.	Normal charge rate (8 hours) per positive plate.	Type and number of plates.					
		Gould.		Chloride.		Willard.	
		Manufacturers type.	Number of plates.	Manufacturers type.	Number of plates.	Manufacturers type.	Number of plates.
	Amperes.						
3 by 4 inches	¾	GGW	2	BT	2	CC	2
3 by 4 inches	1	CW	3				
4 by 4 inches	1¼	CL	3				
5 by 5 inches	1½			CT	2	DC	2
5 by 5 inches	2	CX	3				
6 by 6 inches	2½	CM	3	D	3–13		
5 by 8¾ inches	3	CY	3	PT	2	BC	2
7¾ by 7¾ inches	4½			ET	2	EC	2
7¾ by 7¾ inches	5	CN N	3 5–15	E	5–15	E	5–15
8 by 9 inches	6	CZ	3				
10½ by 10½ inches	10	O	5–13				
10½ by 11 inches	10			F	9–27	F	9–27

In all of the above types, except the two-plate type, there is one more negative than positive plate. All two-plate types have one negative and one positive plate.

ADDITIONAL INSTRUCTIONS FOR ERECTING STORAGE BATTERIES.

Storage batteries, when received at storerooms, should be placed in a dry location and an effort made to erect the batteries as soon as possible after their receipt. When unpacked, preparations should be made to handle each group of elements as a unit. After the lead elements are unpacked, care must be used in handling so that the plates and lugs will not be bent or broken. This can be accomplished by lifting the plates with a stick placed under all the lugs of each element, which can then be lowered carefully in the jars. Care must be used to prevent breaking the tank or jar, or bending the plates of supporting lugs. Types of storage battery racks suitable for cells of the sizes installed by the Signal Corps are shown in figures 1–13 and 1–14. These can be made of any sound timber with the necessary strength, which can be secured locally; all boltheads carefully puttied over, the whole given several coats of acid-proof paint. The rack is then located in its permanent position, and if the battery room has an asphalt floor, provision is made for wide bases for the uprights of the rack to prevent them sinking into the floor. The rack should be carefully leveled before the batteries are installed. The stringers must be of sufficient strength to support the cells rigidly and perfectly level. The insulators should be placed, and the wood tanks or sand trays and glass jars carefully aligned, care being taken that they do not touch each other. If bolt connections are used, they should be thoroughly cleaned by scraping. The strap lugs should also be scraped where they will be in contact, and all connections bolted tight and then painted with an insulating paint. The leads to the storage battery from the switchboard room should be lead-covered cable if possible. The sheath should be cut back about 8 inches from the end. The terminal lugs should then be sweated onto the end of the conductor by filling the hole in the terminal lug with melted resin solder, into which the wire is forced after being carefully cleaned and tinned. The insulation and the shank of the lug is then carefully taped up and given several coats of acid-proof paint. Where the lead rises from the floor, loricated conduit can be used to protect it from injury.

The sand trays and sand must be carefully dried before being installed. The trays can be dried by ordinary methods, but the sand must be baked for a sufficient time to insure that all moisture has been expelled. Before commencing the intitial filling of the jars with electrolyte, if wood separators are

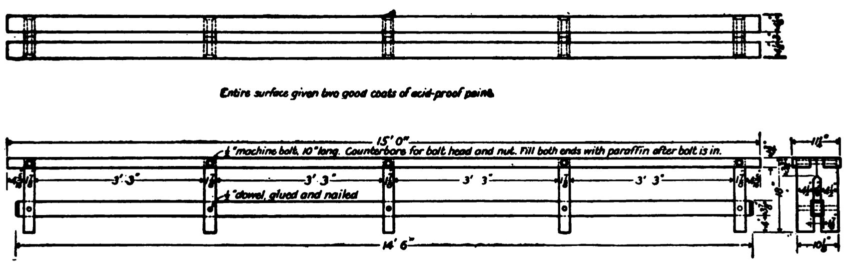

Fig. 1-13.—BATTERY, STORAGE, TELEPHONE, STAND FOR.

used, they should be installed and arrangements should be made to do the work rapidly. A sufficient number of glass or earthenware jars must be available so that several men can be engaged in the filling of the battery jars with electrolyte. It is essential that the electrolyte be kept clean during this process, and every precaution should be taken to that end. Electrolyte of the proper specific gravity is furnished with each battery by the maker. Care should be taken that a sufficient amount of electrolyte of the correct specific gravity is available before the filling is commenced. It should be known with absolute certainty that the required power for the necessary length of time will be available before an initial charge is commenced. The maximum voltage available for charging should be at least 2.75 volts for every cell to be charged, and the amperage available that required by the type of cell.

CARE OF STORAGE BATTERIES.

Excessive charging must be avoided. A battery should not be undercharged, overdischarged, or let to stand completely discharged.

Battery should preferably be charged at the normal rate. It is important that it should be sufficiently charged, but the charge should not be continued beyond that point. Both from the standpoint of efficiency and life of the plates the best practice is the method which embraces what may be called a

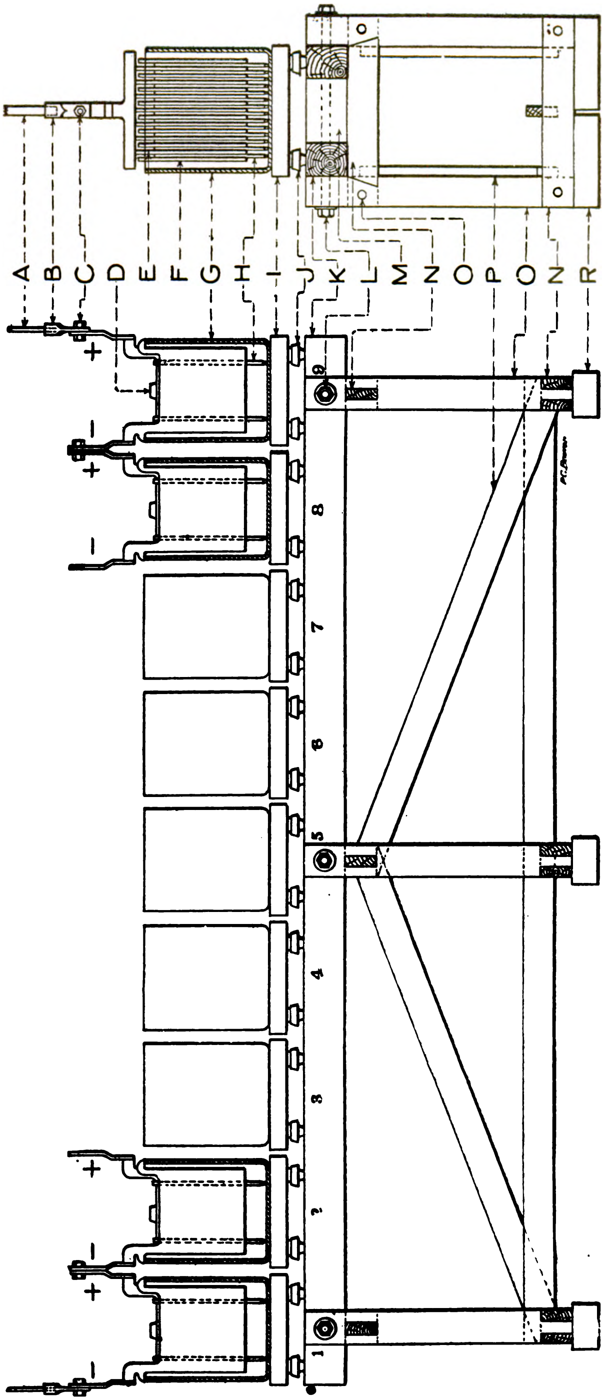

Fig. 1–14.—BATTERY, STORAGE, TELEPHONE, STAND FOR.

regular charge, to be given when battery is from one-half to two-thirds discharged, and an overcharge to be given once every week.

A "pilot cell" should be selected, one that is readily accessible, and at the same time representative of the battery as a whole. The surface of the electrolyte in this cell must be kept at a fixed height, three-fourths inch above the top of the plates, by adding a small quantity of water occasionally. This cell is to be used particularly in following the charge and indicating when it should be stopped. Where batteries are not equipped with the full number of plates, the excess electrolyte in the pilot cell should be displaced by a properly treated and weighted wooden block.

REGULAR CHARGE.

The normal rate should be used throughout the charge when conditions permit; but if it is necessary to hasten the charge a maximum charging rate as given in the table which follows may be used during the first part of the charge; that is, until the cells begin to gas, when it should be reduced to normal. Do not charge at a higher rate than normal after the cells are gassing. The indications of sufficient charge are as follows:

(*a*) The gravity of the pilot cell having risen to a point which is five points (0.005 specific gravity) below the maximum reached on the preceding overcharge; for instance, if the maximum reached on the preceding overcharge was 1.209, the gravity to be reached on the regular charge is 1.204. If the cells are but partially filled with plates and the excess electrolyte is not displaced, the limit should be three points (0.003 specific gravity) instead of five points (0.005 specific gravity).

Type.	D.						E.						F.			
Size of plates (not including lugs).	6 by 6 inches.						7¾ by 7¾ inches..						11 by 10½ inches.			
Number of plates per cell	3	5	7	9	11	13	5	7	9	11	13	15	9	11	13	15
Normal rate (amperes) charge and discharge	2½	5	7½	10	12½	15	10	15	20	25	30	35	40	50	60	70
Maximum charge rate (amperes)	3½	7	10½	14	17½	21	14	21	28	35	42	49	56	70	84	98
Range in specific gravity (approximate) for complete discharge[1]	12	18	25	20	30	25	22	30	33	37	40	42	30	32	42	45

[1] For example: If the specific gravity of a type E–7 cell is 1.207 when fully charged, it will be completely discharged when the gravity has fallen about 30 points (0.030 sp. gr.), i. e., to about 1.177 specific gravity

(*b*) The voltage across battery having risen to a point which is 0.05 to 0.10 volt per cell below what it was on the preceding overcharge, the charging rate being the same in both cases; for instance, if the maximum voltage per cell attained on the overcharge is 2.52, the voltage per cell to be reached on the regular charge is from 2.42 to 2.47 volts per cell.

(*c*) The cells all gassing moderately.

OVERCHARGE.

Once a week, and preferably on the same day of the week, the regular charge should be prolonged until the conditions given below are fulfilled:

If rate is less than normal, the time at maximum must be proportionately increased.

(*a*) The gravity of the pilot cell having reached a maximum, five successive 15-minute readings of this cell showing no further rise.

(*b*) The voltage across battery having reached a maximum, five successive 15-minute readings showing no further rise, the charging rate being kept constant.

(*c*) The cells all gassing freely.

As the temperature affects the gravity, this must be considered and correction made as follows: To correct to normal temperature (70° F.), subtract one point (0.001 specific gravity) for each 3° F. below 70° and add one point for each 3° F. above 70°. For instance, electrolyte, which is 1.213 at 61° and 1.207 at 79°, will be 1.210 at 70°.

GENERAL.

After the completion of a charge and the current off, the voltage will quite rapidly fall to about 2.05 volts per cell and there remain while on open circuit; falling to 2 volts when the discharge is started.

Also, after the completion of a charge, particularly an overcharge, the specific gravity of the electrolyte will rise slightly, due to passing off of the gas bubbles formed during the charge. For this reason all of the pilot-cell gravity readings must be taken before the charging current is cut off.

The voltage should not be allowed to fall below 1.75 volts per cell with current at normal rate; the limiting voltage, however, is higher if the rate is less than normal, and lower if the rate is above normal.

The specific gravity falls very closely in direct proportion to the ampere hours discharged and can therefore be used as a guide in following the discharge; thus, with the cells equipped with the full number of plates or the pilot cell with a displacing block, the range in gravity from full charge to complete discharge is as given in the preceding table. If the cells have not the full number of plates and therefore have an excess of electrolyte, the range is proportionately decreased, as is also the case where the capacity of the battery has decreased due to normal wear or to abuse. If the discharge is at higher rates than normal, the gravity range is reduced in proportion to the reduced ampere hour capacity at the higher rates.

The gravity and voltage limits are not necessarily reached at the same time; but either being reached, the discharge should be stopped.

The specific gravity of the pilot cell (or the battery voltage and current if the pilot-cell method is not used) should be read and recorded just before the beginning and end of every charge; also the temperature of the pilot cell at the end of charge.

A specific-gravity reading of all cells should be taken and recorded once a week, just before the start of charge on overcharge day and also, if the battery is not overcharged weekly, at the corresponding time on the off week. If not practicable to take these readings on overcharge day, they may be taken the day before. Individual cell voltage readings are to be taken just before end of overcharge with current flowing at normal rate. Open-circuit voltage readings are of no value.

Just before the overcharge every cell should be inspected carefully, paying especial attention to any cells noted as *low* in the weekly readings. Make sure that the hanging lugs are in place and not touching adjoining lugs; also any peculiarity in the color of the plates should be noted. Near the end of the overcharge all cells should be looked over to see that they are gassing freely.

In case a cell falls off in specific gravity or in voltage relative to the rest of the cells, or shows lack or deficiency of gassing on overcharge as compared with surrounding cells, or shows the color of the plates markedly lighter or darker than the surrounding cells, the cause should at once be determined and removed.

Short circuits are to be removed with a thin strip of hard wood; never use metal.

If, after the cause of the trouble has been removed, the readings do not come up at the end of the overcharge, then the cell must be cut out of circuit on the discharge, to be cut in again just before beginning the next charge. If this does not bring it up, the process should be repeated.

Impurities in the electrolyte will also cause a cell to work irregularly. Should it be known that any impurity has gotten into a cell, it should be removed at once. In case removal is delayed and any considerable amount of foreign matter becomes dissolved in the electrolyte, this solution should be replaced with new immediately, thoroughly flushing the cell with water before putting in the new electrolyte. If in doubt as to whether the electrolyte contains impurities, a half-pint sample, taken at the end of discharge, should be submitted to the department signal officer for test.

The accumulation of sediment in the bottom of the jars must be watched and not allowed to touch the plates, as if this occurs rapid deterioration will result. To remove the sediment from type D and E cells, first prepare in a suitable receptacle, such as a glass, earthenware, or lead-lined tank, enough new electrolyte of 1.210 specific gravity to fill several cells. Starting at one end of the battery, remove several elements, pressing the plates together to avoid disturbing the separators; siphon or pour off the electrolyte, taking care to disturb the sediment as little as possible; clean the jars, examine element for damaged separators, and replace with new where necessary; put the element back and fill the cells with the new electrolyte at once, so that the elements will not dry. Then add enough 1.400 specific gravity acid to the old electrolyte drawn from these cells to bring it up to 1.210 specific gravity, so that it can be used to fill the next two or three cells cleaned, and so on throughout the battery. The 1.400 specific gravity acid must never be added directly to the cells. Before bolting cells together, the lugs should be well scraped at point of contact. At completion of the work give a long charge until the gravity and voltage have been at a maximum for from 5 to 10 hours. At the end of this charge read the gravity of all cells and adjust where necessary to normal (1.205 to 1.215). Type F cells, on account of their size and weight, can usually be best cleaned by either the " scoop " or " water circulation " methods, though if care is exercised the sediment can be removed as described above.

NOTE.—Very often it will be found that the depth of sediment is greatest under the middle plates, and if the sediment is leveled over the bottom of the cell its removal will not be necessary for some time longer. The leveling can be done by using an L-shaped device, which has no metal in its construction.

Water only is lost by evaporation and must be replaced with water. Do not allow the surface of the electrolyte to get below the top of the plates; keep it at its proper level (one-half to three-fourths inch above the top of the plates) by the addition of pure water, which should be added at the beginning of a charge, preferably the overcharge. It will not be necessary to add new electrolyte, except at long intervals or when removing sediment. To transport or store the water, use clean glass or rubber vessels. Wooden receptacles, if they have not been used for other purposes, may also be used, but they should be allowed to stand full of water for a week before use. In case of doubt as to the purity of the water, a quart sample should be submitted for test.

Ordinarily it will not be necessary to add new electrolyte, except at long intervals (once every year or two) or following removal of sediment. When the specific gravity of cells in good condition at full charge and at normal temperature (70° F.) has fallen to 1.190, it should be restored to standard

(1.205 to 1.215) by the addition of new electrolyte of 1.210 specific gravity instead of water when replacing evaporation. If the overcharge gravity is considerably below 1.190, as is sometimes the case after removing sediment, the quickest way to raise the gravity is to draw off the electrolyte from one cell, refill it with electrolyte of 1.210 specific gravity, and add sufficient 1.400 specific gravity acid to that drawn off from the first cell to raise it to 1.210, then draw off the electrolyte from the second cell and refill with this 1.210 electrolyte, and so on throughout the battery. Never under any circumstances add electrolyte of higher gravity than 1.210 directly to the cells.

If it is not convenient to procure the electrolyte already mixed and ready for use, it may be prepared by diluting sulphuric acid of 1.840 specific gravity or 66° Baumé (oil of vitriol), which has been made especially for storage battery use, with pure water (preferably distilled) in the proportion of one part acid to four and one-third of water by volume; 1.400 specific gravity acid may be reduced to 1.210 specific gravity by mixing equal volumes of the acid and pure water. It is absolutely essential that both the acid and water should be practically free from impurities, such as iron, nitric or hydrochloric acid. When mixing, slowly pour the acid into the water (not the water into the acid) and thoroughly stir with a wooden paddle. The final specific gravity must be read when the solution is cool. A metal vessel must not be used for mixing or handling the solution; a glazed or earthenware crock or a lead-lined tank is suitable, or a wooden vessel which has not been used for any other purpose, such as a new washtub, can be used for mixing, but not for storing, the electrolyte. The electrolyte must be cool when poured into the cells.

When charging, those end cells which may have been successively cut into circuit on discharge should be cut out again on the following charge as soon as they are charged as shown by their gassing moderately. The cells which were last cut into circuit on discharge will, of course, become charged before those that were first cut in. All the end cells, whether used or not, should be cut into circuit at the beginning of the overcharge and each cell kept in circuit until it gasses freely, but no longer.

If the battery is to stand idle or be used at infrequent intervals, an overcharge should be given every two weeks. Several storage battery companies have advised that during such a period exercising or discharging battery through artificial resistance, which for years was the custom, is unnecessary and, in fact, is a wear and tear on the battery.

If the use of the battery is to be entirely discontinued for a period not longer than about nine months and it is not practical to charge at least once a month, care should be taken that an overcharge is given just before the idle period. Water should be added to the cells during the overcharge so that the gassing will insure thorough mixing. The level of the electrolyte should be about one-quarter inch from the top of the jars. After the overcharge is completed, remove the fuses to prevent the use of the battery during the idle period. Though not likely, the level of the electrolyte may, due to excessive evaporation during the idle period, fall below the top of the plates; if this should occur, add water to keep them covered; if in a place where freezing is apt to occur, stir the electrolyte after adding the water, as thoroughly mixed electrolyte will not freeze solid.

If the battery is to be entirely out of service for over nine months, then proceed as follows: After thoroughly charging, siphon off the electrolyte (which may be used again) into thoroughly cleaned glass rceptacles, and as each cell becomes empty immediately fill it with fresh, pure water. When water is in all the cells, allow the battery to stand 12 or 15 hours. Remove and throw away the wood separators. Next siphon the water out of each cell, and the battery can then be allowed to stand indefinitely. If there is any considerable amount of sediment in the cells, it should be removed before it dries.

If the electrolyte has not been withdrawn, all that is necessary to place battery in commission is to add water, if needed, to the cells and give an overcharge until the gravity of the electrolyte has ceased rising over a period of five hours.

If the battery has been standing without electrolyte, proceed as follows: Equip cells with new separators and fill with either new electrolyte of 1.210 specific gravity or, if the old electrolyte has been saved, add enough new of 1.210 specific gravity to replace loss. Charge for 35 hours at the normal rate, or for a proportionately longer time at a lower rate. If the gravity after the first charge is low, it should be restored to standard.

CHAPTER 2.

TELEGRAPHY AND THE INDUCTION TELEGRAPH SET.

THE MORSE TELEGRAPH.

The two methods of arranging the ordinary Morse circuits are called the "open" and "closed" circuit systems.

The latter is frequently called the American system, a diagram of which is shown in figure 2–1. In this only one line battery is necessary, although in practice it is found better to divide the battery between the terminal stations as shown, care being taken not to connect the batteries in opposition. Each key is furnished with a circuit-closer lever, and when the line is not in use the current is constantly flowing, keeping the relays and sounders closed. When operator at any station opens the circuit by means of the lever, he con-

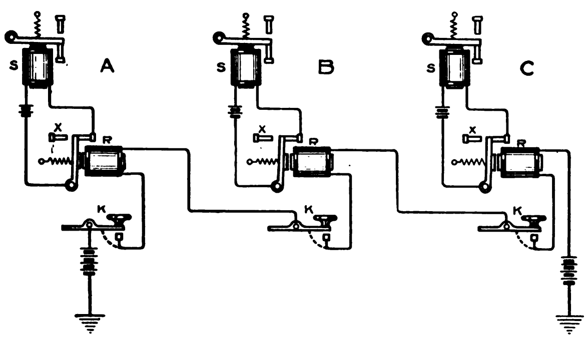

Fig. 2–1.—TELEGRAPH SYSTEM, CLOSED CIRCUIT.

trols it entirely with the key. This system is in universal use in the United States and Canada.

A diagram of the open-circuit telegraph system is shown in figure 2–2. With this system each station must have sufficient main-line battery to operate all relays in the circuit. The keys have a front and back contact (see fig. 2–5). When the line is not in use there is no current flowing and when operating key at any station is depressed, the back contact of that key is opened and the main-line battery to the front contact is placed in the circuit which operates all relays on the line. The relay is sometimes placed in the line connected to back contact, in which case the home relay is not operated. By this means the resistance of the circuit is diminished approximately 150 ohms, which is the resistance of the main-line relay. However, the American operator usually prefers having the relay connected as shown in the diagram, so that the home relay will operate, thereby operating the home sounder.

This system has been used exclusively on the short Signal Corps submarine cables. It obviates the constant application of battery to the cable, as would result from use of the closed-circuit system.

Telegraph Office Equipments.

The familiar essential instruments of the ordinary Morse telegraph office need but brief mention, as it is assumed that the reader is already familiar with the first principles of telegraphy.

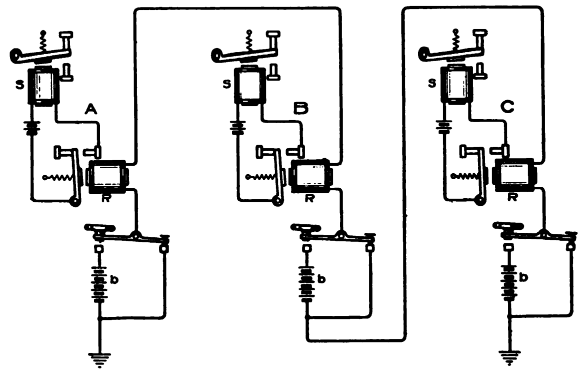

Fig. 2–2.—TELEGRAPH SYSTEM, OPEN CIRCUIT.

The ordinary American Morse or closed-circuit key is shown in figure 2–3. The lever *A* is ordinarily of steel nickel plated; the milled-head screw *F* adjusts the tension of the spring below it. *O* is the base which supports the

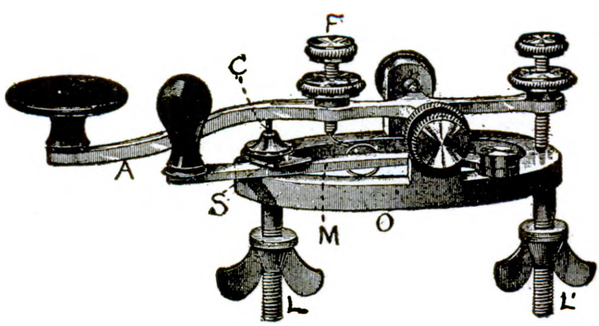

Fig. 2–3.—TELEGRAPH KEY, CLOSED CIRCUIT, LEG TYPE.

trunnion bearings of the key. *M* is the circuit-closer lever, which is pivoted at the rear and slips under a curved metal piece *S*, which is insu-

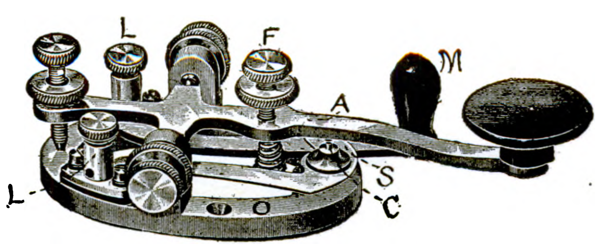

Fig. 2–4.—TELEGRAPH KEY, CLOSED CIRCUIT LEGLESS TYPE.

lated from the base, but in connection with the front leg *L*. This front leg is connected with the relay and the back leg *L'* to the battery or other line if it is a "way" office. *C* represents the upper and lower contact points of platinum, this metal resisting the corroding action of the spark produced on opening the key.

The legless key is shown in figure 2–4. The binding posts instead of the legs are connected to line and battery, respectively. The parts corresponding to the leg key are similarly lettered.

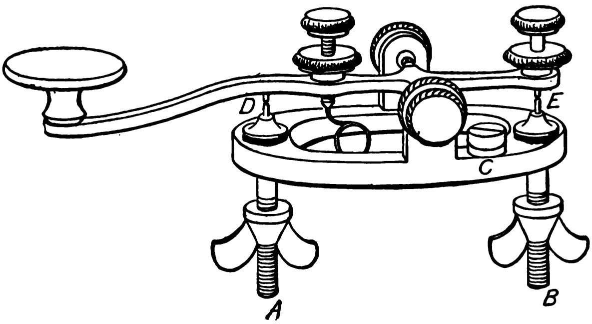

Fig. 2–5.—TELEGRAPH KEY, OPEN CIRCUIT, LEG TYPE.

The "open-circuit" key has an insulated front and an insulated back contact, and the circuit-closing lever is dispensed with. As shown in figure 2–5, the screw *C* on the base of the key is connected with the relay, the insulated lower front contact, *D*, with the battery, and the insulated back contact, *E*, with the ground at a terminal station or with the outgoing wire at a "way" station.

The open circuit key, legless type, may also be supplied.

THE RELAY.

The function of the relay is, briefly, to cause a comparatively powerful local current through a sounder to be controlled by a much feebler one in the main-

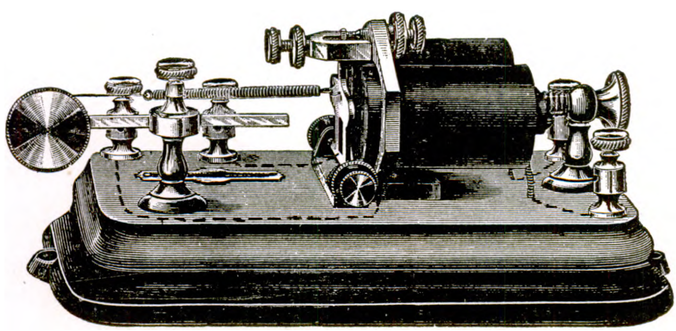
Fig. 2–6.—TELEGRAPH, RELAY, MAIN LINE.

line circuit. The relay coils are included in the main-line circuit, the two binding posts on the right (fig. 2–6) being connected with the key and line, respectively, the binding posts on the left being connected with the sounder and local battery, respectively. The main and local circuits are indicated by the broken lines. The resistance of the relay coils is now almost universally 150 ohms, although on some short lines a "pony" relay of 20 ohms is used.

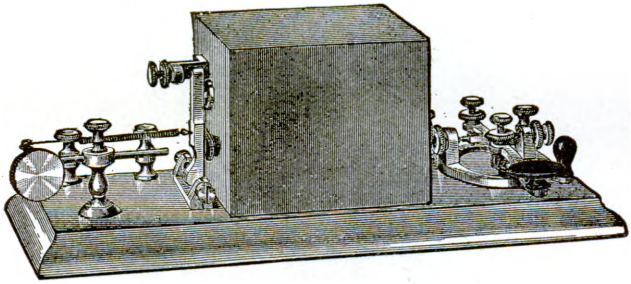

Fig. 2-7.—TELEGRAPH, BOX RELAY.

The box relay with the key on the base is shown in figure 2-7. This relay has a heavier lever for giving a louder sound than that of the ordinary relay, the resonance of the box assisting. As it may be used at temporary field offices,

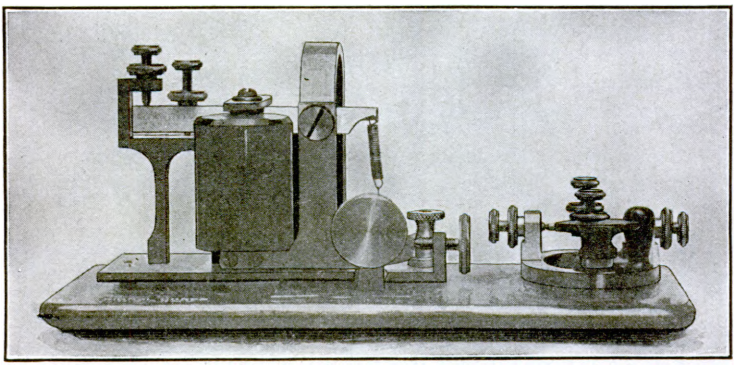

Fig. 2-8.—TELEGRAPH, MAIN LINE SOUNDER.

when local batteries are not obtainable, and is of great strength and simplicity, it is a most useful instrument for military lines.

The "main-line sounder" (fig. 2-8) is somewhat of an improvement on the box relay. The coils are usually wound to 150 ohms, the same as other main-line instruments.

The "pocket relay" is a compact form of main-line sounder for testing purposes. About 40 milliamperes current is required to operate the 150-ohm instrument to best advantage.

THE SOUNDER.

This well-known instrument is shown in figure 2-9, this being one of the most common forms now in use. Its connection with the relay and local battery circuit has already been indicated. The coils are usually wound to a resistance of 4 ohms, and it requires about one-fourth ampere to operate the sounder as vigorously as is required for ordinary offices. Hence two bluestone cells, each having about 1 volt E M F and 2 ohms internal resistance, will give the required current.

$$\left(I=\frac{E}{R};\ .25=\frac{2}{2\times2+4}.\right)$$

If the sounder is connected in circuit with cells of higher E M F and lower resistance, some resistance wire should be inserted to keep the current down to one-fourth

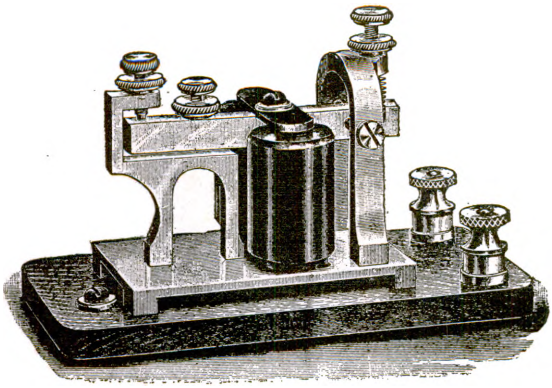

Fig. 2-9.—TELEGRAPH, 4-OHM SOUNDER.

ampere; otherwise the battery will be used up wastefully. For example, with a Fuller cell of 1.8 volts E M F and one-fourt hohm internal resistance, $I=\frac{1.8}{\frac{1}{4}+4}=.42$ ampere, which is considerably more current than necessary. The necessary added resistance, X, can be found as follows: Required current is .25 ampere, so $.25=\frac{1.8}{4+\frac{1}{4}+X}$; $1.06+.25\,X=1.8$; $X=3$ ohms, the "dead resistance" to be introduced in circuit.

In cases when a number of sounders are fed from one storage cell, a "dead resistance" of 4 ohms should be inserted in each sounder circuit, as the storage cell has virtually no internal resistance and an E. M. F. of 2 volts.

SWITCHBOARDS.

These are either terminal or intermediate in their use, and as there is considerable difference in extent and character of the wiring they will be considered separately.

The intermediate or way-station switchboard is represented in simplest form in figure 2–10. Suppose two lines coming into a station are brought to

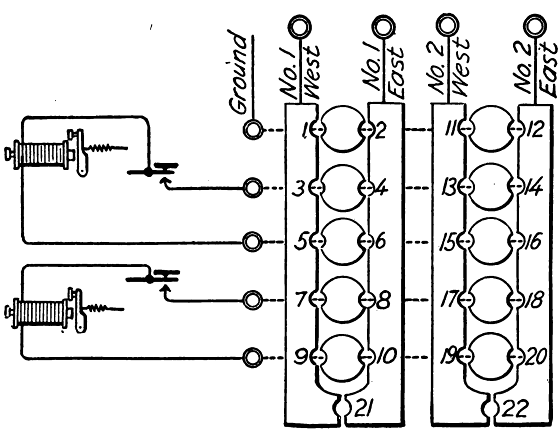

Fig. 2–10.—TELEGRAPH SWITCHBOARD, INTERMEDIATE.

the tops of the vertical strips of brass, as shown, usually through lightning arresters. Between these vertical strips of brass are vertical rows of brass disks, all the disks in any horizontal row being connected together by a metal strip on the back of the board. Semicircular spaces are cut adjoining each other in the strips and disks so connections may be made at any of these points between the disks and strips by the insertion of conical metal plugs with hard-rubber heads. By means of these, sets of instruments may be connected up with each other, the different lines, or the ground. To cut out a set of instruments insert plugs at 21 or 22. To cut in the upper set on line No. 1 take plug out of 21 and insert plugs at 4 and 5 or 3 and 6. To cut upper set in on line No. 2 remove plugs from 3, 4, 5, 6, and 22 and insert them at 13 and 16 or at 14 and 15. In a similar manner the lower set of office instruments may be cut in on either line.

Suppose either of the home sets is cut in on No. 1 line and an open circuit in the line develops. To ascertain whether the open circuit is east or west of the station proceed as follows: Insert plug at No. 2. If communication is established the defective line will be east of station. If communication is not established insert plug at No. 1, when communication will be established with station east of home station unless both lines are open. The foregoing illustrates the use of the ground wire.

Due to defects in one of the lines, the main office may desire a "patch" made. This means that it is desired to cross connect lines 1 and 2. Suppose the chief operator directs that line No. 1 west be connected with line No. 2 east. Of course it is desired to keep one of the sets cut in at this office on this patched line.

Plugs are inserted at 3 and 16 and all other plugs are removed.

To patch No. 1 east with No. 2 west, put plugs at 4 and 15.

To loop No. 1 west with No. 2 west, put plugs at 3 and 15, if desired to leave instruments in. If desired to leave them out, insert plug at 13 instead of at 15.

If directed to ground this loop, as may be needed sometimes in testing, insert a plug at either 1 or 11.

The simplest form of office switch, called a plug cut-out, is shown in figure 2-11. The line wires come in from above, the wires to instruments come out

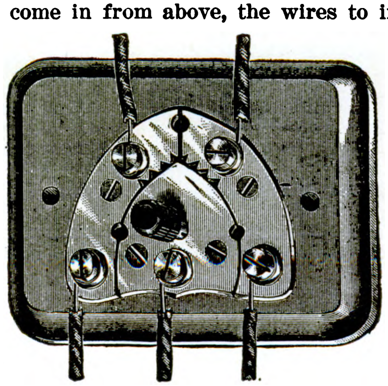

Fig. 2-11.—TELEGRAPH, PLUG SWITCH AND LIGHTNING ARRESTER.

below, and the central wire leads to ground. The insertion of the plug in the lower holes grounds "east" or "west," and when in the upper hole cuts out the station. The central ground plate near the line strips acts as a lightning arrester.

LIGHTNING ARRESTERS.

The principle in general upon which these are made is to bring the line or some of the first metal parts to which it is connected in the office close to a conductor connected directly to the ground. The lightning jumps to this ground connection instead of going through the instruments. These arresters are frequently parts of the switchboard, consisting of a metal plate connected to the ground, extending across the vertical line straps and not quite touching them, or of a series of brass disks extending closely over the straps, the disks being all connected to the ground wire. A simple form of arrester is shown in figure 2–11, being part of the plug cut-out.

The Mason lightning arrester, fully described in chapter 6 of this manual, is sometimes used in protecting telegraph apparatus, and cables where connection is made to aerial lines.

TERMINAL OFFICE SWITCHBOARD AND BATTERY ARRANGEMENTS.

The general plan of the terminal switchboard is shown in ngure 2–12, introducing a row of spring jacks at the bottom of the board. The method of utilizing these in cutting in sets of instruments by insertion of the double flat plugs is shown. These flat plugs, with hard-rubber insulation between the metal strips composing them, are connected with flexible insulated double-conducting cords leading to the sets of instruments. It will be seen that each line comes in through a fuse wire to the top spring contact of the jack, and, if no plug is inserted, passes through the back contact and up to one of the vertical straps of the board. The insertion of a round conical plug at the appropriate disk connects it to the battery and ground. The insertion of a flat plug and cord leading to a set will introduce that instrument into the circuit. The various arrangements for interconnecting, the provision for duplex and repeater sets,

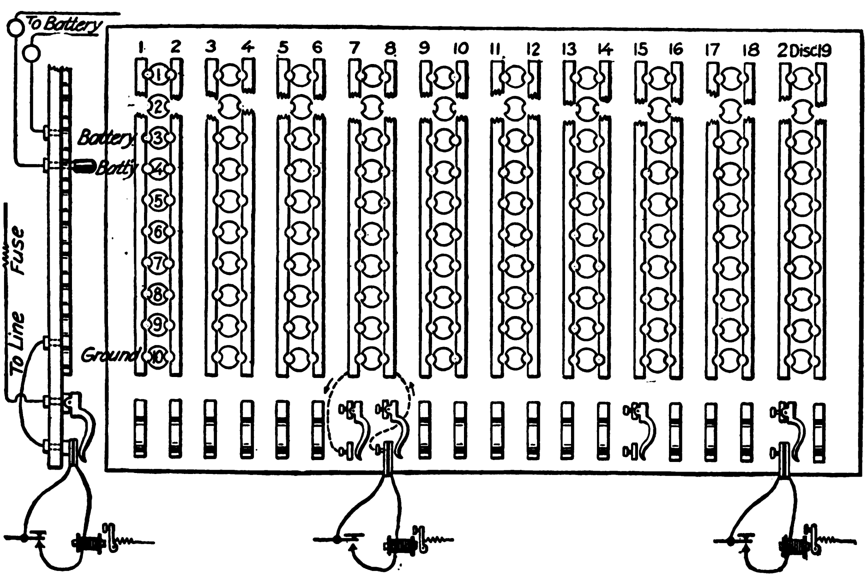

Fig. 2–12.—TELEGRAPH SWITCHBOARD, TERMINAL TYPE.

and the connections for loop switches can be studied out, especially if the reader will consult Maver's American Telegraphy and Jones's Pocket Edition of Diagrams, etc., both of which have been consulted in preparing the diagrams and above descriptions.

As most modern terminal and repeating offices are now provided with storage battery and dynamo sources of current, the method of supplying the terminal switchboard and its connecting lines will be described in the general scheme outlined in figure 2-13.

With the wire *E F* disconnected and the + and — mains connected as shown in the dotted lines, the cells are connected to the dynamo in two rows in parallel for charging. When completely charged they are disconnected at *C* and *D* and reconnected by *E F*. This puts the 60 cells in series again with the negative end to ground. At various points (10, 20, 30, etc.) taps are taken off, through incandescent lamps introduced as safety resistances, to various horizontal rows of disks on the switchboard. Thus, beginning at the top, this row of disks is at the highest potential (120), and a conical plug inserted, connecting any disk of this row with the line leading to the vertical strap through the jack at the bottom, will give the strongest current, and so on down the rows to 10, which brings into the circuit only the last 5 cells next to the grounded end of the battery. The low internal resistance of the storage battery permits feeding almost any number of lines out of the same row of cells without interference. The introduction of lamp resistances is necessary because of this low internal resistance of the cells, as a grounding of the line close to the terminal office would otherwise cause a current dangerous to the instruments. The amount of lamp resistance to be inserted at each potential is, according to Jones, in his

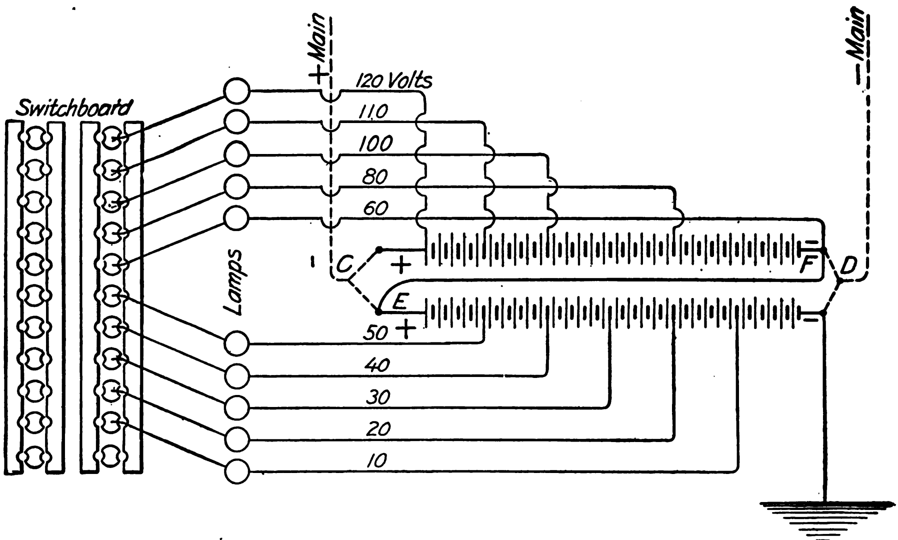

Fig. 2-13.—TELEGRAPH SWITCHBOARD, POWER CONNECTIONS.

Pocket Edition of Diagrams, etc., 2 ohms for each volt. One ordinary 16-candlepower lamp would be about right for the 110-volt potential, and two of these in parallel for the 50-volt potential.

Telegraph Repeaters.[1]

THE MILLIKEN REPEATER.

This was one of the earliest repeaters introduced into the telegraph service, and it is still a standard repeater of the principal telegraph companies of this country. The Signal Corps has a number in use in connection with telegraph lines in Alaska.

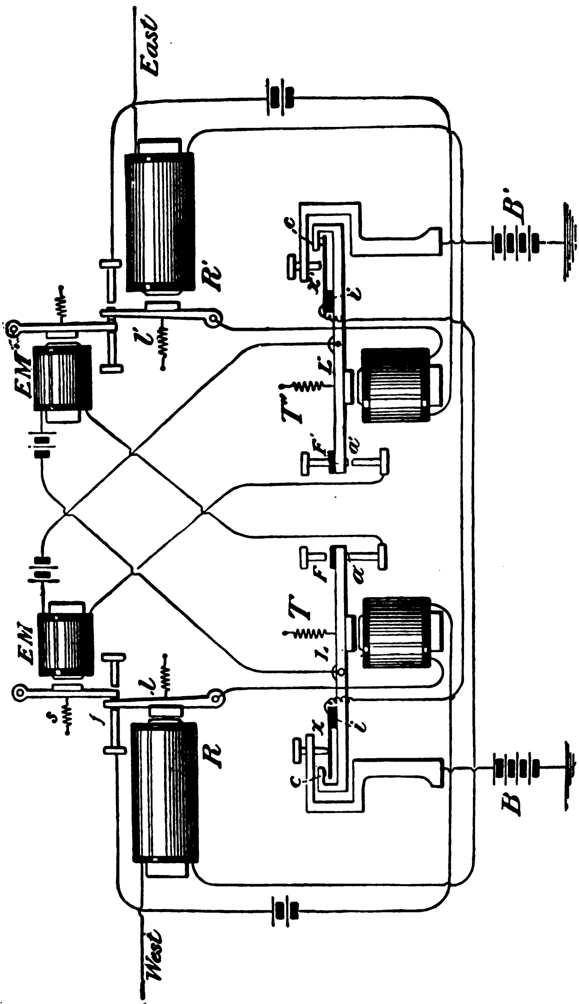

Fig. 2-14.—TELEGRAPH REPEATER, MILLIKEN, THEORY.

This repeater may perhaps be termed an automatic electromechanical repeater, for, while electricity is the controlling force in the performance of its automatic functions, the ultimate action is mechanical.

Figure 2-14 is a theoretical diagram of the connections of the Milliken repeater. *R* and *R'* are the main-line relays. *EM* and *EM'* are extra magnets,

[1] The descriptions and diagrams of the Milliken and Weiny repeaters are taken by permission from Maver's American Telegraphy.

which in practice are supported on metal standards that hold them rigidly in their respective positions relative to the main-line relays. The armature levers of the extra relays are pivoted at the top as shown. *T* and *T'* are transmitters. The levers *L L'* of the transmitters are insulated from the tongues *x x'* at points *i i'* and from screw posts *F F'* by small pieces of hard rubber.

The working of this repeater may perhaps be best described by assuming that the east is about to send. To that end he opens his key; that opens relay *R'* and its lever *l'* falls back, as in the figure, and opens the local circuit controlling the transmitter *T'*. As the latter instrument opens, it breaks the local circuit of *EM* at *a'*; the retractile spring *S* of extra magnet *EM* at once pulls its lever against the lever *l* of relay *R* as in figure, and the transmitter *T'* opens the western circuit at *x'*; this demagnetizes relay *R*, and its spring would withdraw its lever *l* from its front stop *f*, thereby opening the transmitter *T*, and consequently the eastern circuit at *x*, but that, as already stated, the lever of *EM* is against lever *l*, holding it on its front stop, and thus keeping the local circuit of *T* closed. When the east again closes his key, relay *R'* also closes; consequently so does *T'*. This action closes *EM*, and the lever of that intrument is withdrawn from its position against the lever *R*. This releases *R*'s lever, but, as now the western circuit is closed at *x'*, the lever *l* is held forward by its armature.

In this way the function of the repeater in keeping closed the opposite transmitter, and virtually also the circuit which is being "repeated" into, is performed.

Should the west now desire to "break" or send to the east, he opens his key, which action, by opening the local circuit of transmitter *T* at *F*, opens the eastern circuit at *x*. The east, finding his circuit now open, closes his key to await the remarks of the west, when the "repeating" actions just described are reversed.

THE WEINY REPEATER.

This repeater, which is in operation on the lines of the United Press, the Postal Telegraph Co., and Signal Corps, is shown in figure 2–15. The opposite transmitter is kept closed at the repeating station by the action of an extra magnet added to the main-line relays, the construction and operation of which is, briefly, as follows: The extra magnet is wound, as shown, with two coils, through which a current flows from a local battery in opposite directions around the core, so that the latter is normally not magnetized. When, however, one of these extra coils is opened the current in the other coil magnetizes the core. The wire which is joined to both coils of the extra magnet goes directly to the right-hand end of the opposite local battery. The other end of each coil passes to the other pole of the same battery, one coil by way of the left side of frame and the other by way of the lever of the opposite transmitter, as shown. This lever is insulated from the left-hand post when the transmitter is open. Consequently, when the left-hand transmitter is open, as in figure, the circuit of the left-hand coil of the extra magnet of the eastern relay is open at the left-hand post of the western transmitter, and as a result thereof that extra magnet is magnetized by the current passing through the right-hand coil, and hence the armature lever of that relay is held against its front stop. Thus, for example, when, as in the figure, the west sends to the east, and thereby opens his key, the western relay in the repeating office opens and its armature lever falls back, opening the local circuit of the western transmitter. As this transmitter opens it first breaks, at its left-hand post, the circuit of the left-hand coil of the extra magnet of the eastern relay, and next opens the eastern main-line circuit at the right-hand post. As, however, the armature of the eastern relay is kept closed in the manner stated by its extra magnet, the eastern circuit remains unbroken in the repeating station.

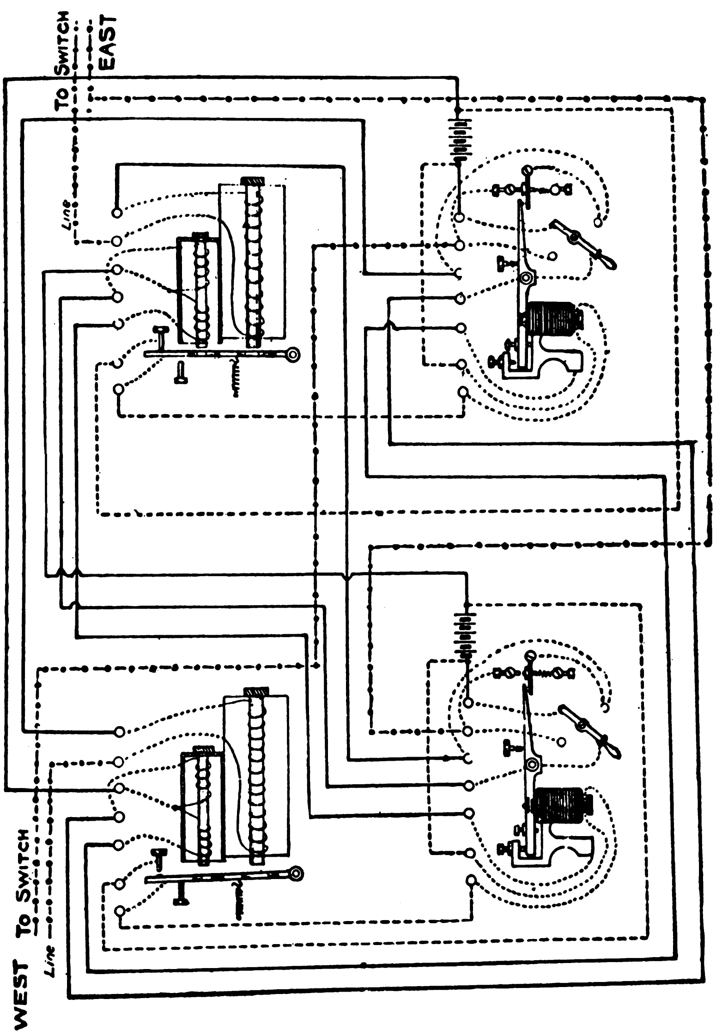

Fig. 2–15.—TELEGRAPH REPEATER, WEINY, THEORY.

The local battery, it will be seen, is also utilized to operate its respective transmitter. A button switch is placed on the base of each transmiter for the purpose of short-circuiting the main-line contact points on the transmitter when it is desired to use the transmitter simply as a sounder for the relay.

Figures 2–16 show the circuits of a telegraph repeater which is used in repeating signals from open-circuit telegraph systems to closed-circuit telegraph systems, or vice versa.

Operation.—The illustration shows the normal position of all instruments when receiving.

To send from open-circuit station, move the two-point switch to battery; this puts current to line through back contact of key. Close the key; this takes battery from line, thus permitting the spring to withdraw the armature from

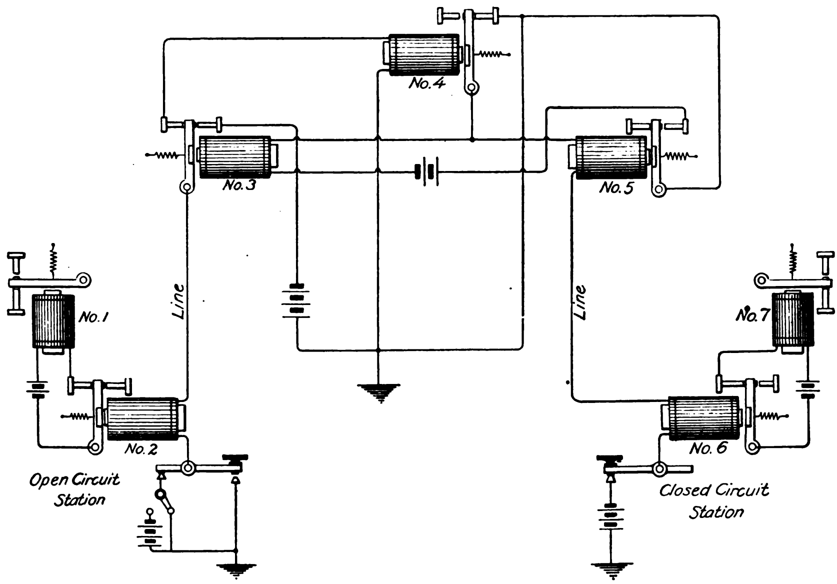

Fig. 2-16.—TELEGRAPH REPEATER CIRCUITS FOR O. C. AND C. C. OPERATION.

relay No. 2, closing the local sounder circuit at its back contact. At the same time relay No. 4 is deenergized, permitting its armature to close the circuit for the closed-circuit station at its back contact. Thus it is seen that closing the open-circuit key causes its sounder to close, at the same time closing the distant closed station. Now open the open-circuit key. This puts the battery to line, which causes the armature of relay No. 2 to be attracted, which opens the local circuit of its sounder; at the same time the armature of relay No. 4 is attracted, which opens the circuit for the open-circuit station. Thus it is seen that a signal at the open-circuit station is reproduced at the closed-circuit station. When through sending, move two-point switch to the other stop — to ground.

To send from the closed-circuit station, open the key, which opens the local sounder circuit; at the same time relay No. 5 is demagnetized, thus permitting its relay to close a local circuit at its back contact. A local battery energizes relay No. 3, which attracts its armature, thus closing a circuit for a battery to energize the open-circuit station, relay No. 2; this opens the sounder circuit at that station.

Now close the key. This closes the local sounder circuit; relay No. 5 attracts its armature, thus opening the local circuit for relay No. 3. The latter is thus deenergized and permits the retractile spring to withdraw the armature from its front contact, thus eliminating all battery from the open-circuit line; then relay No. 2 permits its armature to close the open-circuit sounder circuit at its back contact.

It is now seen that signals sent from either station are automatically repeated to the other.

The two lines are always in an opposite electrical state, which they should be.

The closed-circuit station has the ordinary apparatus.

The open-circuit station must reverse the contacts of its relay and connect battery to line on its back contact; also, it requires a two-way switch to cut out battery when not sending.

If desired, a combination key may be utilized for the ordinary open-circuit key; in this case he two-point switch shown, is not required.

For best results relay No. 5 should be the same kind as No. 6. Also relay No. 4 should be the same kind as No. 2. No. 3 may be of any desired resistance or nature, as it is on an independent local circuit.

No. 5 relay is in the closed-circuit line, and No. 4 relay is in the open-circuit line.

The local sounder battery at the open-circuit station must be a closed-circuit one. The other batteries are all of the open-circuit type.

The following should be observed in the adjustment and care of telegraph repeaters:

The distance between cores of magnets and armature operated thereby should be no greater than necessary to prevent armature from sticking. Controlling magnets once adjusted for obtaining maximum strength seldom require further adjustment.

Adjustments should be so fine that a considerable change in the temperature of the room will so alter the distance between contact points that they will require readjustment. With such adjustments a particle of dust will sometimes bridge the contact points, and they should be cleaned daily, or more frequently if necessary.

An extra relay in each circuit at repeater stations makes it possible for a repeater attendant to know beyond doubt just how the signals are received at distant stations. This obviates depending on the varying judgment of men at different stations. He can send rapid signals and observe exactly how they pass through repeaters.

The repeater should be so located that contacts are readily accessible and that light can be seen between the contact points or reflected to them by means of white paper, thereby obtaining the same result. The repeating point of the repeating sounder armature is on a spring which admits, if the adjustment is correct, the repeating point to be opened only after the rigid points on this armature which control the extra or controlling magnets have opened.

TEST FOR OPERATION OF TELEGRAPH REPEATERS.

A thorough knowledge of the operation of telegraph repeaters, personal interest, and a comparatively small amount of time are necessary in order that attendants may become proficient in the care of telegraph repeaters.

MILLIKEN REPEATERS.

Figure references below refer to figure 2–14. The extra relay in each circuit at repeater station recommended in the foregoing is not shown in figure 2–14.

Slowly raise the left end of the armature of the repeating sounder *T'*. This will break the circuit of the controlling magnet *EM*, and the return of its armature will be distinctly heard. The next instant the spring contact *x'* of the repeating sounder *T'* will be opened, thereby opening the circuit leading to the relay *R*, extra relay (not shown), and line. The opening click of the armature of the extra relay will be distinctly heard. It will be noted that in the above operation the armature of the relay *R* is held in the closed position by the armature of the extra magnet *EM* even though the relay *R* be deenergized.

REVERSE OPERATION.

Upon lowering by hand the armature of the repeating sounder *T'*, the spring contact will first be closed and at the same instant the closing of the armature of extra relay mentioned above will be heard. At the next instant the rigid contact points *A'* close, thereby closing the circuit to the extra magnet *E M*. This draws the extra magnet armature away from the armature *L* of relay *R*.

WEINY REPEATERS.

With Weiny repeaters the effect is the same; the opposite controlling armature, instead of falling back as in the Milliken, is held in position due to the opening of one winding only of the two differentially wound coils of the magnet. This fact is indicated by a sound emanating only from its armature. In rapid sending the difference between the opening and closing of rigid and springy contact points can not be detected, but nevertheless the difference must exist before the repeaters will operate satisfactorily, for should both open simultaneously, uneven, ragged signals will result.

DUPLEX TELEGRAPHY.

[Condensed from "American Telegraph Practice," McNicol.]

By duplex telegraphy is meant a system which makes possible the transmission of two messages over a single wire at the same time, one in each direction.

THE SINGLE-CURRENT DUPLEX.

The most important elements of the single-current duplex are the transmitter, the differential relay, the artificial-line rheostat, and the condenser.

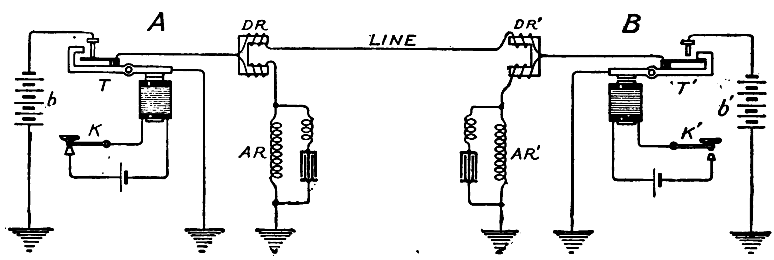

Fig. 2-17.—TELEGRAPHY, DUPLEX, SINGLE CURRENT, THEORETICAL CONNECTIONS.

The single-current duplex is sometimes referred to as the Stearns duplex, in honor of the inventor, Mr. Joseph B. Stearns.

In single Morse circuits, the armatures of all relays in the circuit, including that at the home station and that at the distant station, are operated simultaneously when any signaling key connected into the circuit is manipulated.

When it is required to transmit a message in each direction over a line simultaneously, it is evident that the receiving relay at each of the two terminal stations must respond to the manipulations of the signaling key at the distant station, and not to the operation of the key at the home station.

Figure 2-17 is a diagram of the theoretical connections of the single-current duplex. A line is shown extending between stations *A* and *B*. *T* and *T'* are the transmitters, *DR* and *DR'* the differential relays, *AR* and *AR'* the artificial-line rheostats, and *b* and *b'* the main-line batteries at *A* and *B* respectively. The function of the transmitter is simply that of a signaling key connected into the main-line circuit in such a manner that when the key is closed battery is applied to the line, and when the key is opened the line is grounded.

Figure 2–18 shows a key connected into the main-line circuit direct, to do the work of a transmitter. Here, as in the case of the transmitter shown in figure 2–17, it is apparent that when the key is depressed, battery is applied to the line, and when the key is opened the line is grounded.

In the operation of duplexes—as will be explained more fully later—it is essential that in the operation of the transmitter or of the key the shortest possible interval of time shall elapse between the instant battery is removed from the main line and the instant the ground connection is substituted therefor. Obviously if an ordinary key were used to control the application of battery and removal of ground connection, and vice versa, in the act of signaling, the lapse of time between these two contacts would be excessive, due to the comparatively slow movement of the hand in working the key, being more pronounced the wider the gap maintained between the contacts of the key. Also, were the ordinary key used directly in the line circuit, the speed of operation would be considerably curtailed owing to the requirement imposed

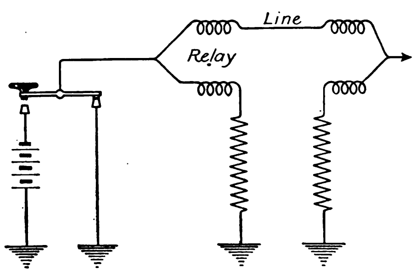

Fig. 2–18.—TELEGRAPHY, DUPLEX, SINGLE CURRENT, THEORETICAL CONNECTIONS.

upon the operator to make equally firm and solid contact between the key lever and the ground connection as between the lever and the battery contact; a condition that the average operator would find quite difficult to meet.

The transmitter, therefore, is used for the purpose of insuring instantaneous transfer of the line connection from battery contact to ground contact in response to the operation of the key which controls the operation locally of the transmitter, regardless of whether the key is operated rapidly or slowly.

By noting the construction of the transmitter shown in connection with the diagram, figure 2–17, it may be seen that the moving element of the instrument may be so adjusted that at the instant the battery is removed the ground contact is made, and thus the continuity of the line is preserved, or, in other words, the period during which the line is open is reduced to a minimum. This is a requirement of considerable consequence in the operation of multiplex telegraphs.

All that is required in a differential relay is that when currents of equal strength pass through both windings of the differential magnet, the cores shall not become magnetized. It is to be remembered, however, that the amount of magnetism produced in either core is directly dependent upon the strength of current flowing in the winding around the core, and if the magnetic effect produced by one of the coils is to be exactly neutralized by that of the other, it is essential that the current strength in the two coils be equal.

If the current strength in one coil is greater than that in the other coil, naturally the excess current produces a certain amount of magnetism which is not neutralized and, due to this magnetism, the armature of the relay is attracted.

It is already understood that the strength of the current flowing in a circuit is dependent upon the value of the applied e. m. f. and upon the ohmic resistance of the circuit. In the case of the differential relay, therefore, it is essential that if the relay is to be truly differential the current strength in both windings must be identical, and this in turn imposes the requirement that the resistance of each circuit must be identical.

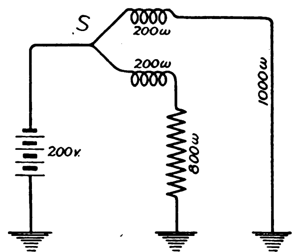

Fig. 2-19.—TELEGRAPHY, DUPLEX, SINGLE CURRENT, THEORETICAL CONNECTIONS.

Suppose a differential relay having a resistance of 200 ohms in each winding is connected with a source of e. m. f. so that current flows through both coils as indicated in figure 2-19. If it is required that the cores of the relay magnets shall not be magnetized, it is necessary that equal current values obtain in each of the divided paths to ground. The fact that the resistance of each of the relay coils is the same is of little consequence unless the circuits beyond the relay also are of equal resistance.

In figure 2-19 current passes through one coil of the relay and beyond through a line wire having 1,000 ohms resistance, thence to ground. The other coil of the relay forms a portion of a path to ground through a resistance coil of 800 ohms. It is evident, therefore, that as the current divides at *S*, it has two paths to ground, one having a resistance of 1,000 ohms and the other a resistance of 1,200 ohms, and it is apparent that there will be more current flowing in the circuit having less resistance than in the other. As a consequence, one core of the relay is to a certain extent magnetized, due to the extra current in one coil of the relay over that in the other coil.

The resistance of main-line wires varies from a few hundred ohms to several thousand ohms and where differential relays are used in duplex operation, in order to insure that equal current values obtain in each coil of the relay when the home battery is applied to the line and the distant end of the line is grounded, it is necessary to have at the home station an adjustable resistance through which the other coil of the relay may be connected to ground.

Obviously if this resistance is adjusted to have a value equal to that of the line wire to the distant station, like current values will exist in both coils of the relay, and there will not be any magnetism produced in the cores of the relay.

The adjustable resistance used to equate the resistance of the main-line wire is generally called the artificial line.

THE ARTIFICIAL LINE.

All line wires possess electrostatic capacity. The quantity of electric charge accumulated upon the surface of the conductor depends upon the superficial area of the conductor, upon the distance intervening between the conductor and the earth (or between the conductor concerned and other conductors in electrical contact with the earth), and upon the nature of the insulating medium intervening between the line wire and the earth. In any line of considerable length a portion of the current is bound up in the form of static charge.

The first rush of current into the line at the instant the battery is applied thereto (sometimes referred to as the current of charge) for an instant produces a much greater magnetic effect upon the armature of the home relay than obtains when the entire line has been fully charged and permanent conditions established in the circuit.

The result of the initial inrush of current, greatly exceeding in volume, as it does, the final current, is that a false signal or " kick " of the relay armature is produced. The energy of the kick depends upon the electrostatic capacity of the line, being greater where the capacity is high, and less pronounced as the static charge taken on by the line wire is less.

Also, there is to be considered the effect of static discharge, which occurs at the instant the line wire is shifted from the battery connection to the ground connection upon opening the key controlling the operation of the transmitter. At this instant the electrostatic charge, which has been accumulated upon the surface of the conductor, flows back to ground by way of the ground contact of the transmitter, passing through the main-line coil of the differential relay, again producing kick of the relay armature.

In view of these considerations, therefore, it is necessary if the false signals which are produced at the beginning and the end of each intended signal are to be neutralized or nullified that the artificial line be made to possess properties identical with those of the main-line wire; i. e., resistance and capacity.

The application of the condenser as an adjunct of the artificial line gives to the latter the desired property of electrostatic capacity.

A condsenser path to ground via the artificial-line coil of the differential relay results in an initial rush of current through that coil at the instant battery is applied to the line, which, by means of adjustable " timing " resistances in series therewith, may be made to exactly equal in strength and duration the corresponding rush of current which takes place at the same instant through the main-line coil of the relay, thus at the critical moment insuring identical current values in both coils of the relay.

And, further, when the line wire is shifted from battery contact to the ground connection, at the moment the key is opened the discharge from the condenser associated with the artificial line takes place through the relay coil, forming a portion of the artificial-line circuit at the same instant that the main line discharges through the relay coil, forming a portion of the main-line circuit, thus again at the critical moment insuring equal current values in the two coils.

To understand the import of the above remarks, one must have in mind the positions of the main-line circuit and of the artificial-line circuit through the windings of the respective relay coils, also that the magnet made up by the artificial-line relay coil and the magnet made up by the main-line relay coil both control the same armature.

When the relay is operated by current from the distant station its operation is due to a surplus of current in the main-line coil over what may be in the artificial-line coil of the relay.

When the signaling keys at each end of the line are closed and like poles of battery are applied at both ends of the line, the desired signal is made by the home battery on the home relay and is the result of a surplus of current in the artificial-line coil of the relay over what may be in the main-line coil.

When, due to electrostatic charge or discharge of the main line, the current in the main-line coil of the relay is augmented above that traversing the artificial-line coil of the relay, a false signal will be produced unless at that instant the current flowing in the artificial-line side of the relay is increased to an equal value. This is what is accomplished by using condensers and retardation resistance coils in connection with the artificial line.

DOUBLE-CURRENT DUPLEX SYSTEMS.

As a result of the development of more efficient and satisfactory duplex systems, the single-current duplex is rarely used in this country, except where it is combined with the polar duplex in forming the differential quadruplex system of telegraphy by means of which two messages are sent in each direction over a single wire simultaneously.

THE POLAR DUPLEX.

The essential elements of the polar duplex are a battery pole changer, a differentially wound polarized relay, an artificial line rheostat, and an artificial capacity.

THE POLE CHANGER.

The transmitter shown in connection with the single-current duplex, figure 2–17, has connected to one of its contacts the positive pole of a main-line battery and to the other contact a circuit to ground. If to the latter the negative pole of a main-line battery were connected instead of the ground wire, closing the signaling key would send to line a positive impulse, and opening the key would send to line a negative impulse, in which case the transmitter might correctly be regarded as serving as a pole changer, inasmuch as the polarity of the battery placed in contact with the line wire changes from positive to negative and vice versa each time the transmitter tongue is caused to break contact with the positive battery terminal and make contact with the negative battery terminal.

The introduction of the double-current duplex called for the substitution of a transmitter in place of the type of instrument used with the single-current duplex, which would meet the changed conditions.

The new form of transmitter, or pole changer as it has since been termed, provides for the maintenance of an air gap, as the main-line contact is shifted from one pole of the battery to the other.

So far as the polar duplex is concerned, the same necessity does not exist for the employment of a continuity preserving transmitter as was the case with the single-current duplex, the reason for which will be explained.

THE POLAR RELAY.

All of the inherent difficulties experienced in the operation of single Morse lines are encountered in the operation of the single-current differential duplex system.

During favorable weather and where a high degree of line insulation is maintained both of these methods of telegraphy are satisfactory. But when, due to excessive leakage conductance, the current values at the receiving end are low, considerable difficulty is experienced in maintaining satisfactory operation.

The polar duplex overcomes this difficulty to a great extent, and by means of this system lines may be worked satisfactorily long after adverse weather conditions have rendered single Morse and single-current duplex systems inoperative.

Figure 2–20 shows a theoretical view of the magnetic circuit of the polar relay.

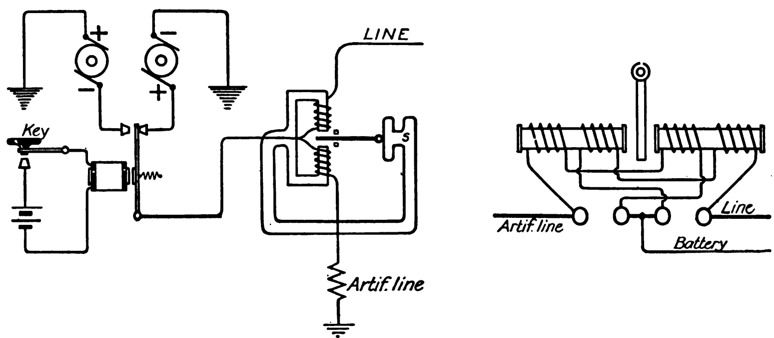

Fig. 2–20.—TELEGRAPHY, DUPLEX, POLARIZED RELAY, THEORETICAL CONNECTIONS.

It will be seen that the windings are identical with those of the ordinary single-current differential relay. Current from the battery flows through the windings in opposite directions, the action of one coil neutralizing that of the other, the result of which is that the core is not magnetized so far as any action due to the current from the battery is concerned.

The fundamental difference between the two instruments is that in the polar relay the tongue is held on either side, due to the magnetic pull of the permanent magnet which constitutes the cores of the electromagnets.

In the case of the common differential relay, the armature tongue is held in the closed position by the action of either or both magnet coils and in the open position by a spiral spring. With the polar relay the armature is drawn into contact with one or the other poles, due to magnetism in the cores, resulting from the action of current in either coil of the instrument. The important feature with the latter relay is that after the armature has once been attracted toward either contact it will remain there, whether current remains in the coil winding or not (provided there is no current in the opposite coil).

Referring to figure 2–20: When the key is operated, the armature lever of the pole changer is caused to make contact, first, with the negative pole terminal and then with the positive pole terminal. If the ohmic resistances of the real line and the artificial line are equal, current from whichever dynamo is connected with the armature lever will flow through the companion windings of the relay differentially, with the result that there is no electromagnetism produced in the cores facing the relay armature. It matters not whether the outgoing current is from a positive source or from a negative source, owing to the fact that it passes through the windings of the relay differentially there will be no magnetism produced, and this irrespective of the polarity of the current flowing in the circuit.

If the key is manipulated, there will be sent out a series of impulses alternating in sign, from positive to negative each time the key is closed and opened, and if the resistance of the artificial line side of the relay balances that of the line side, the armature of the relay will not be affected. Moreover, it will be found that if the relay tongue is moved by hand into contact with its closed contact or with its open contact, it will still remain passive to the outgoing reversals from the pole changer.

The magnets of polar relays are so wound that when current from the distant station flows through the main-line coil, it is given a path through an auxiliary winding in the opposite coil in the reverse direction which results in the permanent-induced magnetism in one of the cores being neutralized, while the magnetism existing in the other core is intensified, causing the armature to be attracted

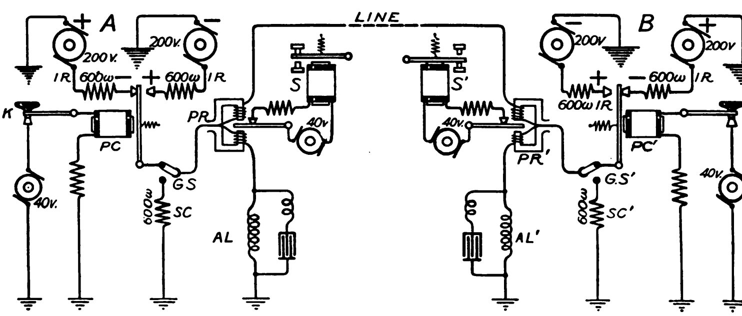

Fig. 2–21.—TELEGRAPHY, DUPLEX, POLAR, CIRCUITS.

toward the opposite contact. The reverse action takes place when the battery poles at the home station and at the distant station are in opposition (like poles to line) in which case the artificial-line coil of the home relay has its magnetism increased, and the line coil has its magnetism neutralized. Thus, due to the action of the current in the coils, the armature is caused to move into contact with the open or the closed contact as desired.

The office of the auxiliary winding in each case is to act as a " clearing out " agency.

There are several distinct types of polar relay used by the various telegraph administrations, each relay having its peculiarities of design, but the principle upon which all polar relays operate is the same.

The artificial line rheostat, and the artificial capacity used in connection with polar duplex apparatus to " balance " the resistance and capacity of the actual line, are the same as those for the single-current duplex.

Operation of the polar duplex.—Figure 2–21 shows the connections of the main-line and local circuits of the polar duplex.

Complete equipment at both ends of a duplexed circuit are shown so that the various operations may be treated with regard to their effects upon the apparatus at both ends of the line.

PC and *PC'* are the pole changers at stations *A* and *B*, respectively, while *PR* and *PR'* are the polar relays, *K* and *K'* the signaling keys, locally controlling the movements of the pole-changer armature in each case.

The dynamos, which furnish current for the operation of the main-line relays, are shown—two at each end. In each case one of the dynamos has its positive terminal connected with the back stop of the pole changer, while the other dynamo has its negative terminal connected with the closed contact of the pole changer.

The resistance coils and condensers, which comprise the artificial line, are, at each end of the main-line circuit, marked *AL* and *AL'*.

In figure 2–21 the pole changers at each end of the line are closed; that is, the armature levers of the pole changers in each case are in contact with their front stops, due to the fact that the signaling keys *K* and *K'* are closed. This places to line at each end a 200-volt negative battery. As the batteries are of equal potential, no current will flow over the main line. At the instant both pole-changer armatures make contact with their back stops—thus placing opposing battery to line—the levers of the polar relays at each end are moved into contact with their back stops, thereby opening the local reading sounder circuits at each end. At this point it is important to gain a correct understanding of why the armatures of the polar relays at each terminal station are attracted toward either contact when the main-line batteries at each end of the line are in opposition. The explanation is that when the terminals of a wire are at equal potential, no current will flow in the wire. Therefore, when like poles of identical potential are to line, as in the case before us, it is apparent that the terminals of the main-line wire are at equal potential. An entirely different condition, however, exists with regard to the artificial line at each end. As, in each case, one end of the artificial line is connected with the earth (which is at zero potential), there is presented to the outgoing currents from each station a path to ground via the artificial line magnet of the polar relay. On each occasion, therefore, when like poles are to line at each end, current from the home battery flows through the artificial line and the armature of the polar relay is attracted toward its back stop if the opposing batteries are positive and toward its front stop if the opposing batteries are negative.

In order to carry on transmission in both directions at the same time it is necessary that the operator at *A* shall be able to control the movements of the armature of the relay at *B* regardless of which pole of his battery *B* has to line. Also, that the operator at *B* shall be able to control the movements of the relay armature at *A* regardless of which pole of his battery *A* has to line.

Suppose the operator at *B* should depress his key (while the key at *A* is open), thereby placing the tongue of this pole changer in contact with the negative pole of the main-line battery at *B*, the result will be that the main-line coil of the relay at *A* will be energized and its tongue attracted toward its closed contact, thereby operating sounder *S*.

It is evident, of course, that current continues to flow through the artificial line coil of the relay at *A*, but owing to the fact that the current strength in the main-line coil of the relay is twice that in the former and in the opposite direction, it is plain that the magnetism in the core of the relay at *A* is reversed, and the armature, as a result thereof, moves into contact with its front stop. If what has previously been stated is true, the armature of the relay at *B* should have remained passive to the reversal of current sent out from *B* when the key at *B* was closed. That this is so is apparent, for, although the magnetism in the artificial line magnet of the relay at *B* has now been neutralized, due to the presence of current in the main-line coil of the relay, the armature is held in the open position by the action of the permanent magnet associated therewith. In other words, nothing has happened so far to cause the armature of the main-line relay at *B* to change its position; therefore, it remains in the position taken when last it was caused to move by a surplus of magnetism in one coil over that obtaining in the other magnet coil. Similarly, when *A* alone closed his signaling key, the relay at *B* responds, while the relay at *A* does not. When the signaling keys at both ends are depressed, the line currents once more are in opposition, and, as in this case, the currents flowing through the artificial lines at each end are in the reverse direction of that taken when both keys were open, the relay armatures at each end are caused to move into contact with their front stops.

In effect, therefore, when the operator at *A* attempts to register a "dot" on the relay at *B*, at the same instant that the operator at *B* intends to register a "dot" on the relay at *A*, each station causes to be produced in his own relay the signal intended to be transmitted from the distant end of the line. Or, the foregoing might be paraphrased thus: The relay at *A* will be closed whenever the key at *B* is depressed, regardless of whether *A* is sending or idle; and the relay at *B* will close whenever the key at *A* is closed whether *B* is sending or idle, but in neither case will the signals transmitted from either end conflict with those originating at the distant station.

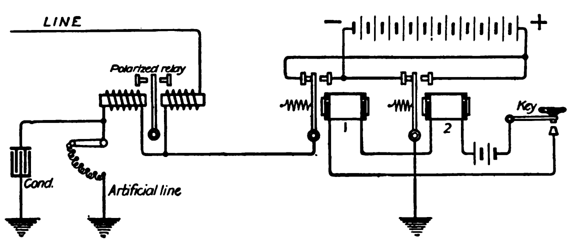

Fig. 2-22.—TELEGRAPHY, DUPLEX, BATTERY.

THE BATTERY DUPLEX.

Figure 2–22 shows the theoretic connections of the main-line instruments used to operate a polar duplex by means of gravity battery.

In this duplex arrangement the pole changer consists of two double-contact relays, or transmitters. The transmitters are connected in series, that is, one signaling key controls the operation of both instruments, so that both armatures are in the closed position at the same time, and in the open position at the same time, depending upon whether the key is open or closed.

It will be seen at a glance that when both armature levers are in contact with their back stops the positive pole of the row of gravity cells is connected to line via the tongue of transmitter No. 1, and at the same time the negative pole of the battery is "grounded" via the tongue of transmitter No. 2. Conversely, when the signaling key is closed and both tongues are against their front stops, the negative pole of the battery is connected to line and the positive terminal of the battery to ground. The operation of the key, controlling as it does simultaneously the operation of both transmitters, results in alternate positive and negative impulses being sent to line, the same as when two dynamos of opposite polarities are used.

In other respects the connections are the same as in the dynamo polar duplex.

THE "BRIDGE" DUPLEX.

The single-current duplex and the polar duplex being based on the differential principle are dependent upon producing an equality of current strengths, while the bridge duplex, which is based upon the well-known Wheatstone bridge principle, is dependent upon producing an equality of potentials.

Figure 2–23 shows two stations *A* and *B* at either end of a line wire equipped with bridge duplex apparatus.

B and *B′* are the main-line batteries at *A* and *B* respectively. *AL* in each case represents the artificial line at either end. *R* and *R′* are two artificial resistances of equal value, likewise *r* and *r′* at station *B*. At each end of the line the relays are connected between the points *c* and *d* of the "bridge" formed by the line wire and the artificial line resistance. Closing the key at *A* sends out a current which divides at *a*, half passing over the line wire to station *B* and reaching earth via the apparatus at that end of the line, while the other half passes through the artificial line at *A*, reaching the earth at that end of the circuit. Inasmuch as the points *c* and *d* are equidistant, ohmically, from

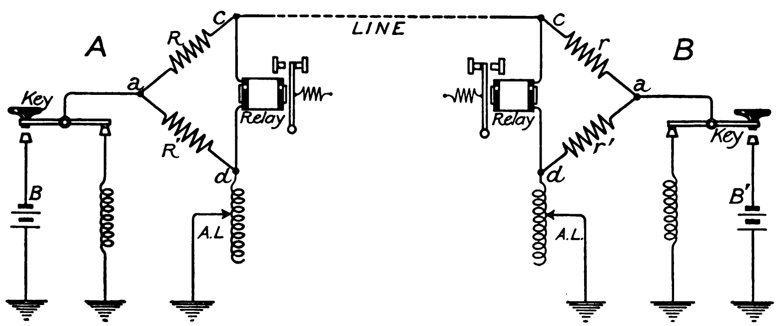

Fig. 2–23—TELEGRAPHY, DUPLEX, BRIDGE, THEORETICAL CONNECTIONS.

the point *a*, their potential values are identical, and no current will flow through the windings of the relay at *A*. This is true, of course, only when the resistance of the artificial line at *A* is made equal to the resistance of the actual line to ground at the distant end. The relay at *A*, therefore, is not affected when *A* sends to *B*. The same condition prevails when *B* alone sends to *A*. Signals from *A* operate the relay at *B* because the incoming signals have a joint path made up of the branches *c–d* and *c–a*, thus setting up a difference of potential between the points *c* and *d* sufficient to operate the relay.

The operations which take place with different key combinations at either end of the bridge duplex may be traced without difficulty.

Since the line relay employed in the bridge duplex does not need to be differentially wound, it is evident that any ordinary relay may be used with this method of duplexing. It is apparent, also, that the outgoing currents do not pass through the windings of the home relay, and, as the currents pass directly to line, there is a minimum amount of retardation in the sending circuit. And, further, it is claimed for the bridge duplex that its line relays, on account of their position in the bridge, are not as responsive to induced line disturbances or to earth currents as are the line relays in the differential duplex. This is due to the fact that in the bridge system only a portion of the line currents pass through the relay, no matter whether the currents are the result of an impressed e. m. f., of induction, or of conduction from neighboring circuits, while in the differential duplex all currents existing in the main line pass through the windings of the line coil of the relay.

The bridge duplex has been more highly developed in Europe than in America, and several of the refinements applied to its operation there are particularly noteworthy as having a bearing on the general subject of high-speed signaling.

BALANCING THE POLAR DUPLEX.

The polar duplex is balanced by asking the distant station to "ground." This he does by throwing the 3-point switch *GS*, figure 2–21, to down position. (Sometimes the left-hand lower "point," or disk, is connected to the earth via *SC*, sometimes it is the right-hand lower point that is so connected.) This action disconnects the pole changer and battery from the line and transfers the latter to the earth via the resistance coil *SC* or *SC'*. These resistance coils are inserted, as in the Stearns duplex, to compensate for the internal resistance of the battery at each end. When the distant switch has been turned the home switch is also similarly turned. The adjusting screw of the polarized relay is turned forward or backward until the armature remains on whichever side it may be placed. The home battery is then placed to the line by turning the switch *GS* to the up position right. Then the pole changer is opened and closed and the resistance in *AL* or *AL'* is adjusted until the armature of the relay remains on either side, as before. This insures a "resistance" balance. The pole changer is now closed and opened rapidly, and if short clicks are heard the capacity of the condenser is varied until these disappear altogether. This shows that a "static" balance has been obtained. A static balance can also be had by asking the distant station to "cut in," which he does by turning the switch to the up position. When he has done so, ask him to close his key, so that the armature of the home relay will rest against its contact point. The armature may then be given a slight bias away from its contact point and the home pole changer again operated. If clicks are still heard in the sounder, the condenser and its resistance coil are adjusted until they disappear, when the distant end may be asked to send a few words, to give an opportunity to readjust the armature to its proper place. As a rule, however, a good working static balance can be obtained on a polar duplex without giving the armature of the polarized relay a bias.

WESTERN UNION POLE CHANGER.

The Western Union standard pole changer for gravity batteries is shown in figure 2–24. The contact points of the instrument are inclosed in a circular glass-incased box. The end of the lever *L* is seen extending into the box through an aperture in the back of the framework. The tension springs *S S'* are insulated from the box. The contacts *C C'* are attached to the framework. The poles of the battery are generally connected to the springs *S S'* by way of their respective binding posts on the side of the baseboard. The lever is connected to the earth, and the contact points *C C'* to the line, or vice versa, as desired; also via the binding posts.

THE ADJUSTMENT OF TELEGRAPH APPARATUS.[1]

If operators in general could be made to realize how much more comfort they might take in their daily work did they but acquire even a slight knowledge of the knack of adjusting their instruments properly, they would certainly

[1] By Willis H. Jones, in the Telegraph Age, September and October, 1902.

make a move in that direction for their own interest if not for that of the company employing them.

There is positively no excuse for the indistinct manner in which signals are so frequently recorded on the really first-class instruments employed by telegraph companies to-day. When the signals do not arrive in proper shape there is some good reason for it, but the theory of the fault given by the average operator is usually wide of the mark, and as he "adjusts" in accordance with his ideas of the trouble, he generally makes matters worse by such efforts.

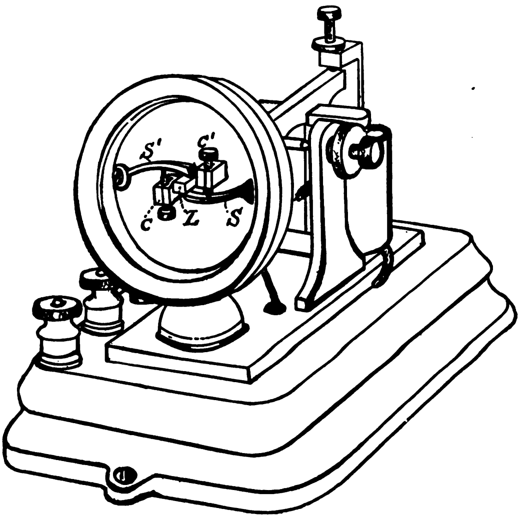

Fig. 2–24.—TELEGRAPHY, DUPLEX, POLE CHANGER.

For the purpose of demonstration let us see what may be learned in the way of adjustment and care of an ordinary single-line relay and sounder. Now, we will assume that the wire, battery, and instrument coils are in first-class order and then introduce a few conditions for the purpose of noting the different effects produced on the apparatus.

Wet-Weather Effects.

In wet weather the quantity of current which traverses the coils of a relay is greatly increased at or near the battery station over and above that which normally flows in clear weather, while distant-station instruments receive less than the usual amount. This condition is caused by the numerous "escapes" or side paths down the poles along the route which draw additional current from the dynamo, all of which must necessarily pass through the relays inserted between them and the battery. Distant relays receive less than they are entitled to, because much of the current on the wire "escapes" down the wet poles before reaching them. Now, a strong current in the coils means a strong magnetic pull on the relay armature, while a weak current, of course, causes a correspondingly weak attraction.

It follows from this that the wet-weather method of adjusting a distant relay is directly opposite to that followed for the home relay at the battery end of the circuit. The operators at distant points must get the magnets closer and closer to the armature as the downfall of rain increases, while the home operator is compelled to draw his relay coils away from it. This seems like a very simple operation to perform, but the manner in which most operators go about it explains why they fail to secure the best results.

The first principle of adjustment lies in maintaining at all times, whether the current is weak or strong, a practically constant or normal tension of the retractile spring attached to the relay armature. The explanation is that a relay spring responds best to the magnetic attraction of the armature when the tension is such that the "curling" is not stretched to any great extent out of its original close-fitting construction when new.

The adjustment should invariably be made by moving the magnet backward or forward by means of the thumbscrew. The tension of the retractile spring need not be altered perceptibly except to give the operation a finishing touch. The habit of stretching the relay spring to meet a strong magnetic pull not only causes the former to work less efficiently at the time, but soon injures it permanently by destroying its sensitiveness.

Feeling for a Distant Station.

It frequently happens in very wet weather that a distant office can not "break" the operator at or near the battery station on account of the difficulty the latter has in getting a fine adjustment. When informed via some othert circuit that such is the case the best method to pursue is as follows: Make a few dots to attract his attention (he will hear you; the distant office has the advantage in this respect) and then tell him to "dot." Now pull the magnets back from the relay armature until the circuit stands apparently just open. Next turn down the retractile spring very slowly until you hear the signals. If you miss them, you may sometimes catch them by placing your finger on the lever of the relay and giving it a gentle pressure back and forth. If the operator is dotting, you will feel the impulses and thus be able to readjust the instrument.

The latter method is an excellent one to pursue on a way wire when in doubt as to whether anyone is using the circuit, for by this precaution one operator need never break in while another is sending. However, as it is only in very wet weather that an operator is bothered to any great extent by the relay, the real source of daily discomfiture usually lies in an improper adjustmnet of the sounder.

ADJUSTMENT OF SOUNDERS.

When a sounder does not give out a loud enough tone to suit an operator, he almost invariably proceeds to give the lever a wider play, as if that was the only remedy. As a matter of fact that process in itself seldom brings about the desired results unless the lever at the time happens to be screwed down abnormally close. The important thing to know is that if you give the lever a play which will permit the armature to move away from the magnet cores beyond a normal distance, the magnet has a hard time getting control of it again. The explanation is that a magnet loses its power to attract the armature in a degree directly proportional to the square of the distance separating them; or, in other words, to the square of the air gap. For example, if two magnets similarly constructed in all respects be fed by an equal strength of current, and the air gap between the cores and the armature of one made the thickness of a cardboard, while two cards could occupy the gap in the second magnet, the former would be practically four times as strong as the latter. It is plain, therefore, that to give the sounder lever too great a play will so weaken the pull on the armature when in its "open" position that when the local circuit is again closed the lever moves so slowly at first that it hardly has time to cross over the space before the current is again broken. The result is that a signal is partially broken up before completion.

The lesson to be learned from this is that the play given to an armature lever must never be so great that the magnet can not bring it back promptly within the time allotted to complete a signal. This, in turn, suggests that the amount of play given should be decreased in proportion to the speed with which the signals are increased. The proper method to increase the volume of sound is as follows:

ADJUSTING FOR MAXIMUM STRENGTH.

Place a sheet of paper between the armature and the poles of the sounder magnet and then lower the former until there is just space enough to move the paper back and forth without catching. This permits the magnet to exert its maximum strength on the lever, and the position should seldom be altered. Whatever changes are necessary during the process of adjusting should be effected by means of the spring, the upper thumbscrew, and those which regulate the trunnion. The adjustment of the trunnion screws is a matter too generally overlooked. It is there that the pitch or quality of the sound is regulated. The pivot must not bind too tightly, nor yet be too loose.

When signals do not reach the operator in the particular style that suits his fancy, he usually attempts to remedy the fault by giving the sounder lever a greater or a lesser play. If the trouble happens to lie in an improper adjustment of that part of the apparatus he may possibly succeed in helping matters, but the fact is that indistinct signals may be due to a great variety of causes, any one of which, in his ignorance, he may never suspect.

For the purpose of illustration, let us again take the case of an ordinary single-line relay and sounder and assume that despite a careful adjustment of the relay and sounder magnets after the manner suggested in the preceding installment of this article the signals continue to "drop out" at times.

The first thing to determine is whether the fault lies in the relay or the sounder. Such disturbances are usually due to a loose or improper connection somewhere in the local circuit, but not always. Naturally the first move made toward locating the trouble should be to examine all binding posts, and operators in general would save themselves many annoyances if they would acquire the habit of doing this whenever they sit down to a different set of instruments. If the binding-post connections prove to be secure, open the key and "dot" or "write" with your finger on the relay armature or lever, using the latter as a key. If the signals then respond firmly and distinct, the local circuit is not faulty, and attention should be directed to the relay.

In many cases the source of the trouble will turn out to be too tight an adjustment of the trunnion binding posts, thus preventing the restrained armature from responding readily to the influence of the magnet. This fault is particularly applicable to circuits in which the strength of the current flowing through the relay coils is weak. Where the main-line current is strong, the magnet is frequently able to overcome this drawback, but it is evident that even then the working margin of that instrument has been cut down to the extent that the trunnion binds. It follows, then, that the trunnion binding posts should always be so adjusted that the crossbar or axis upon which the lever and armature rests may move perfectly free in its sockets.

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If, however, the signals made in the manner suggested continue to drop out despite this precaution, the fault will possibly be found in a loose connection somewhere in the local circuit. If tightening the binding posts fails to remove the trouble, examine the fine wire wound around the shaft of the relay lever, one end of which is attached to the shaft and the other to a part of that trunnion binding post where the local battery makes its exit. If this wire becomes broken, the sounder signals will certainly "drop out" at times owing to the loose connection made between the shaft and the post as the former turns in the socket. The purpose of the fine wire is to bridge over this unavoidable break in the local circuit, and the operator will at once see the necessity of keeping that connection intact.

When a sounder stands "open" and it is desired to ascertain if the break in the local circuit lies in some of the relay connections, place the blade of a knife across both local binding posts (situated just behind the relay spring). If the opening is in that instrument, the sounder will then close. If the latter remains open, try the same method with the two posts of the sounder itself. If the coil or wire connections there are broken, a spark will be noticed the moment the blade makes and breaks contact with the two posts. The sounder, however, will not close, because the magnet coils are cut out.

The knife-blade method, however, should never be resorted to where sounders are connected up in multiple, such as is usually the case in our large modernly equipped offices, because the cutting out of the coil draws so much current through the low-resistance route via the blade that it melts the fuse and opens the other four or five companion sounders comprised in that particular group. Operators see this fact frequently demonstrated in large telegraph offices when someone thoughtlessly or ignorantly permits a steel penholder or other piece of metal to simultaneously make contact with both binding posts of the sounder or resonator connections. When this occurs, the "locals" go off on several adjacent desks and business is suspended until a new fuse is substituted. The blade may be placed across the local posts of the relay, however, because it will not cut out the coils of the magnet, hence the resistance is not lowered. It may also be done where the sounder coils are in series with a loop or lamp resistance, such as the arrangement which obtains with duplex and quadruplex circuits.

It will be seen from what has been stated that the adjustment and understanding of even an ordinary relay and sounder require considerable skill and a fair degree of electrical knowledge, yet an operator who does not possess ambition enough to interest himself to the extent of understanding the instrument before him certainly deserves much of the needless provocations which come his way.

Up to this point the suggestions concerning various methods of adjusting telegraph apparatus have been confined to the receiving instruments. The sending apparatus, however, demands quite as much attention and skill on the part of the operator as the receiving instruments.

Operators, as a rule, hardly realize the fact that with but a very little study on their part it lies within their power to not only make their own work much easier, but that also of the man at the distant end of the circuit.

One of the most common mistakes the operator makes is to find fault with the key frequently because of his inability to send fast or to make the Morse alphabet easily. It may surprise many readers to learn that as a matter of fact the key is seldom to blame. It is really a matter of what is called the electrical and the mechanical inertia of the instruments that cause the trouble.

For example: In a telegraph wire where there are a great many offices close together, such as we find on some railroad circuits, there are necessarily many relays, the highly wound coils of which compose the greater part of the total resistance. Where such a condition exists the counter electromotive force developed within and by the coils is so great that it checks the quick action of the current in its operation of building up the magnetism in the iron cores of the relays, and thus demands a slower rate of speed on the part of the sending operator in order to fully form his characters. Unless he complies with this law the second impluse in the formation of a character will be begun before the preceding one has been fully "built up," with the result that the key will "stick," as he erroneously believes, and the key gets the blame.

With sounders, as usually arranged, the case is different, but the effect is just the same. If you give the lever of a sounder an abnormally great degree of play, and then make "dots" exceedingly rapid, the lever will probably remain in an "open" position during the experiment. Decrease the speed somewhat and it will respond indifferently. If, however, you open and close the key very slowly, the lever will follow the movement faithfully. Finally, if you adjust the lever armature close to the magnet and give it but very little play, every "dot" will be heard, no matter how fast you make them.

The lesson to be learned from these experiments is that where speed is required the lever must be given as little play as practicable in order to reduce the mechanical inertia to a minimum. Where an operator ignores this rule, in order to get a greater volume of sound to receive by, he will experience the same difficulty in forming the alphabet as his friend with the choked relay did, and probably vie with him in condemning the greatly abused key.

The application of these lessons is directed principally to those in charge of duplex and quadruplex apparatus, and cautionary to operators in branch offices working sounders on legs or loop extension. On account of the tongue and the retractile spring on transmitters, and the accuracy with which pole changers must be manipulated, those instruments demand very careful adjustment to the speed of the transmitting operator. Sounders, on the other hand, once properly adjusted, respond so clearly (on the transmitting side) that operators in branch offices working on duplex loops find that the sending side works, apparently, as well on a poor wire as a good one. The result is that in bad weather the fact is frequently overlooked that the pole changer or transmitter, as the case may be, can not perform their functions properly at a dry-weather speed, and thus by maintaining their usual speed cause no end of trouble both to themselves and the quadruplex chief at the main office.

Power for Operating Telegraph Systems.

Most of the large telegraph systems are operated by current obtained direct from generators driven by electric motors.

Where batteries are used for operating telegraph systems, they are frequently of high voltage, and particular attention should be given to insure of their being highly insulated.

With storage batteries for this purpose, if the small porcelain or glass insulators for each cell are furnished so much the better; if not, the shelves should be as well insulated as possible, or strips of glass or small strips of paraffined wood under each cell may be used in an emergency.

In charging some of the smaller types of cells a convenient arrangement is represented in figures 2–25 and 2–26. In this the electric-light mains are connected with the storage cells with some incandescent lamps in parallel, as shown. If 110-volt 32-candlepower carbonized filament lamps are used, each lamp allows approximately 1 ampere of current to pass. So with a type of cell requiring 6 amperes, 6 lamps in parallel would permit the required cur-

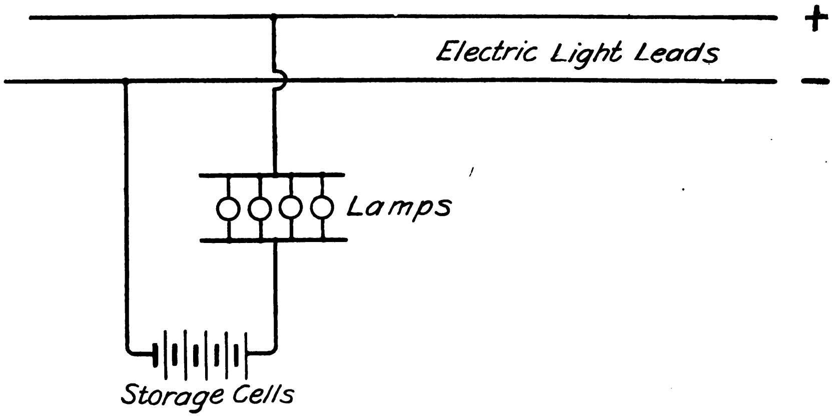


Fig. 2-25.—TELEGRAPHY, POWER, CHARGING STORAGE BATTERY.

rents to pass. Of course the source of supply must be a direct, not an alternating, current.

The diagrams (figs. 2-25 and 2-26) show the arrangement for an office where a constant-current lighting current is available as a supply.

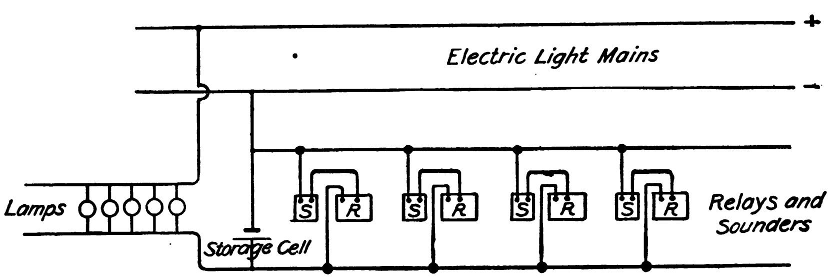


Fig. 2-26.—TELEGRAPHY, POWER, CURRENT FOR RELAYS AND SOUNDERS.

The lamps may be used to illuminate the office, as the opposing E. M. F. of the one-storage cell (fig. 2-26) will not perceptibly diminish their light. As will be noted, the storage cell is constantly in use even while charging.

On account of its low internal resistance, as many sounder circuits in parallel can be fed from one of these storage cells as the capacity of the battery will permit. Each sounder requires one-fourth ampere, so in 24 hours it would require at most 6 ampere hours to supply it. And if the storage cell had a capacity of 50 ampere hours it could supply four sounder circuits 24 hours and still have a reserve for another day in case of accident to the charging circuit.

Induction Telegraph Set.

The induction telegraph set (fig. 2-27) is strictly a portable field instrument which was developed by the Signal Corps. It is designed for sending Morse signals over field lines of communication and other lines where it is difficult

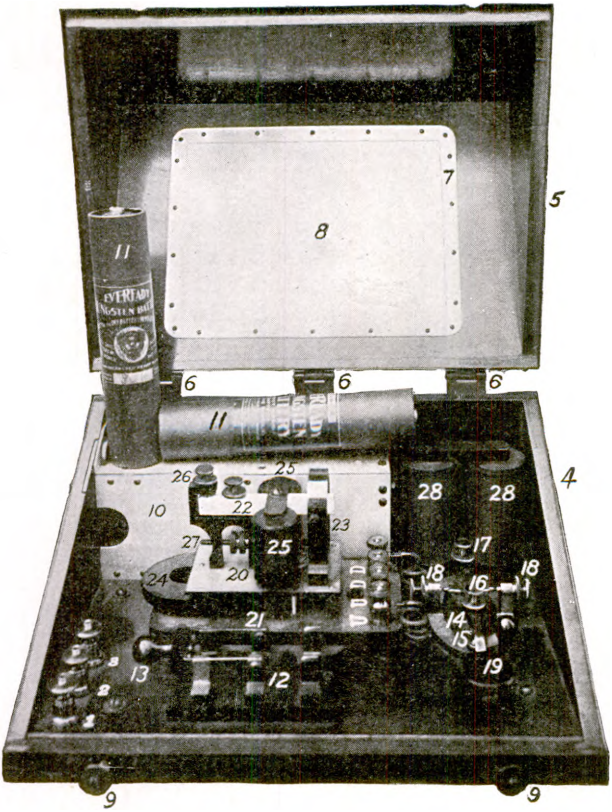


Fig. 2-27.—TELEGRAPH INDUCTION SET.

Part No.	Name.	Reference No.
1	Binding posts, complete	1-2-3
2	Case, complete	4
3	Case, cover for	5
4	Case, hinge for	6
5	Case, circuit diagram frame	7
6	Case, circuit diagram	8
7	Case, circuit diagram, celluloid cover for	....
8	Case, cover fastener, complete	9
9	Case, internal, for battery	10
10	Battery, tungsten, type A (2 units to a set)	11
11	Battery, spring and support for	....
12	Switch, D. P. D. T., complete	12
13	Switch, D. P. D. T., handle for	13
14	Key, complete	14
15	Key, spring for	15
16	Key, spring adjusting screw	16
17	Key, rear adjusting screw	17
18	Key, trunnion screw and lock nut	18
19	Key, handle for	19
20	Sounder, complete	20
21	Sounder base	21
22	Sounder armature	22
23	Sounder armature supports	23
24	Sounder permanent magnet	24
25	Sounder, coils for (2 to a set)	25
26	Sounder, armature movement adjusting screw	26
27	Sounder spring tension adjusting screw	27
28	Induction coil, complete	28
29	Induction coil, coil for (2 to a set)	....

to supply the large amount of battery required for ordinary telegraphic work. It can also be used for the transmission of speech by making certain modifications. The instrument comprises a wooden case the dimensions of which are 11½ by 7¾ by 6 inches, outside. The top of the case contains instructions for operating and a diagram of circuits. A baseboard, which is removable by means of four screws, has on its underside the wiring and has on its upper surface a battery case of aluminum to hold two tungsten batteries; an induction coil of the closed magnetic circuit type; a double contact telegraph key of standard pattern; a polarized sounder, which will be described later; a double-pole double-throw switch for reversing the connections to line, and three binding posts numbered 1, 2, and 3. In addition, authority has been issued by the Chief Signal Officer to install a fourth binding post on all instruments in service, to be connected to the contact of the bottom battery. This is for the purpose of attaching external battery to this instrument and for this purpose the batteries in the case must be removed and external battery connected to binding posts 3 and 4. The line is connected to binding posts 1 and 2 as usual. This set can be used for ordinary Morse telegraphy, in which case the line is connected to binding posts 2 and 3, and the small blocking screw which prevents the switch of the key from being closed should be run down with a screw driver so that the switch may be kept normally closed when not sending.

Previous models of the field induction telegraph set used a polarized relay of a well-known commercial form and, in addition, required a local battery

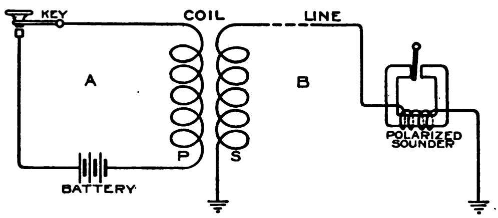


Fig. 2–28.—TELEGRAPH INDUCTION SET, THEORY OF OPERATION.

and local sounder to be connected to the relay tongue. The model 1912 set contains what is known as a "polarized sounder." It consists of a regular local sounder frame, underneath which is mounted a strong permanent magnet, the cores of the coil forming the pole pieces of the magnet. The coils are so wound that a current in one direction tends to increase the strength of the magnet and in the other direction tends to decrease the strength of the magnet. The armature is adjusted by means of a spring so that it remains in either the up or down position when no current is flowing. When an instantaneous current comes over the line due to the depression of the key at the distant station, the direction of winding is such that the magnetism is suddenly increased and the armature is drawn to the down position. It remains there after the instantaneous current has ceased. When the key at the distant station is opened and an instantaneous current in the opposite direction flows through the instrument, the magnetism of the cores is suddenly decreased with the result that the armature flies to the up position and there remains. If the line is not too long nor of too high a resistance, and particularly if there are not too many instruments in series on the line, the sound made by this instrument imitates very closely that made by a local sounder. It may be that the impulses from the distant station will come in reversed, and for this purpose the double-pole double-throw switch is provided which reverses the connection of the sounder to the line. If the signals come in reversed, it is only necessary to turn the switch over when they will come in in the proper direction.

Theory.

Figure 2–28 shows the theory of operation of the field induction set. Circuit *A* comprises a key, primary of an induction coil, and battery. Circuit *B* comprises the secondary of the induction coil and a polarized sounder or relay. When the key is closed in circuit *A* there is an instantaneous electromotive force induced in the secondary of the induction coil which causes an instantaneous current to flow through the polarized instrument and to bring its armature to a certain position in which it will remain after the instantaneous current has ceased. When the key in circuit *A* is opened there will be a similar instantaneous electromotive force tending to make a current flow in the opposite direction in circuit *B*. This current will bring the armature of the polarized instrument to its other position, in which it will remain after the current has ceased. As this secondary electromotive force may be very high, and as polarized instruments can be made to operate on extremely small currents, this induction telegraph arrangement will operate over lines of high resistance, although the battery in the primary circuit may be one of only a few volts.

INSTRUCTIONS FOR OPERATING.

To install batteries.—Open door of the battery case by releasing spring and at the same time, placing the forefinger against the inside of the door through the small aperture in metal case. Insert top battery unit, negative or flat end, first and lower unit, positive or bottom end, first.

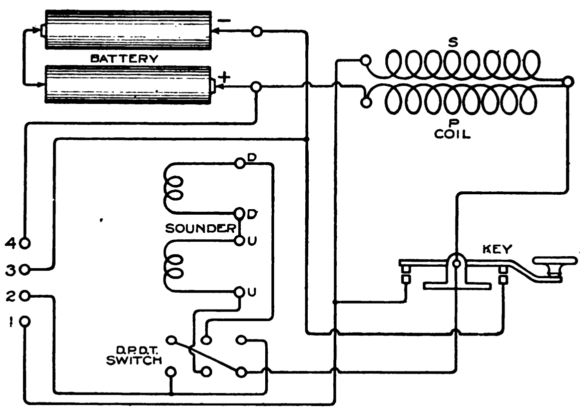


Fig. 2–29.—TELEGRAPH INDUCTION SET, CIRCUITS.

To use as an induction telegraph set.—Connect line to binding posts 1 and 2. Lock circuit closing lever in the open position by unscrewing small setscrew in key base until it projects sufficiently to lock the lever. If the sounder fails to respond, change the direction of the current through the sounder by throwing the reversing switch.

To use as a closed-circuit telegraph set.—Remove batteries from case. Connect line to posts Nos. 2 and 3; release circuit-closing lever by screwing locking screw down until it is flush with the base.

Circuits.—As an induction telegraph; when the key is depressed current from + of battery flows through primary of coil, key, front contact to — of battery. The instantaneous secondary current flows from secondary of coil, through switch, polarized sounder (operating it), to binding post 2, line, distant station, ground, binding post 1, secondary. The instantaneous secondary current on opening the key follows the same path in the opposite direction. Incoming impulses through line to binding post 2 go through the switch, polarized sounder, key, back contact of key, binding post 1, ground. The purpose of the back contact of the key is to short-circuit the secondary of the induction coil and so remove its impedance from the circuit when receiving. It is not essential and the key may be replaced by one having no back contact.

As a closed-circuit telegraph; external battery one pole to ground, the other to binding post 3. Batteries in instrument removed. Circuit, binding post 3, front contact of key, key, reversing switch, sounder, binding post 2, line. Note that circuit closing lever on key must be closed when not sending.

The resistance of the primary of the induction coil installed at present in these instruments is very low, and the batteries run down very quickly in service. All officers in charge of installations using these instruments should keep this in mind and keep constant requisitions for new batteries going forward. Wherever possible, as in permanent or semipermanent stations, external battery should be installed. The type of external battery is immaterial, about 6 to 10 volts being a good E. M. F. to use.

DUPLEX OPERATION.

The field induction telegraph set may easily be duplexed, following the simple principles of the differential polar duplex system. The only additional equipment required is an artificial line which can be adjusted to have the same resistance and, with long lines, the same capacity as the line itself. For duplex operation the line must be connected to binding post No. 2. The green wire normally connected to outside binding post *U* on the polarized sounder must be shifted to inside binding post *U*, and the connecting bar joining inside *U* to inside *D* must be in place. The artifical line goes between outside *U* and binding post No. 1, and the ground is attached to binding post No. 1.

Artificial line for duplex.—Any resistance box, sliding rheostat, or other variable resistance whose maximum value is equal to or greater than the resistance of the line and distant instrument. If the line has appreciable capacity, as in the case of a long line or one in cable or laid on the ground, a balancing capacity can be constructed of the 2 m. f. condensers used in common battery telephones. They are cheap and easily obtained. Fractions of 2 m. f. can be obtained by putting condensers in series. Close static balance is rarely necessary.

Installation.—In large offices the operators should have in front of them only the local sounder and key. All other apparatus should be in a separate room under charge of an expert. This plan is especially necessary where duplex and repeater sets are installed. In small offices the circuits should be well installed without unnecessary complication, and full instructions for operating and adjusting should be furnished. Operators put in charge of such stations should receive special instruction before assuming charge, as the induction telegraph system is not used commercially at present, in spite of its many advantages.

CHAPTER 3.

TELEPHONY—THE CAMP TELEPHONE AND THE BUZZER.

MAGNETISM.

A bar of steel or iron which has the properties of attracting other pieces of steel or iron is called a magnet. When freely suspended at its center it will point north and south. It can also impart these powers to another piece of iron or steel without losing any of its own.

The ends of a magnet are called its poles. The end which points toward the north is its north pole and the other end its south pole. The north end of any magnet will repel the north ends of all other magnets, but will attract all south poles. From this follows the law of magnetic attraction "like poles repel and unlike poles attract."

The force exerted by one magnet on another to attract or repel it is called magnetic force. If iron filings be spread on a paper laid over a bar magnet, the filings will arrange themselves about the magnet in curves which end at the poles. These curves are called lines of force, and the whole space occupied by the curves is the magnetic field of force, or magnetic field. It is assumed that the lines of force come out from the north pole of the magnet, pass through the air, reenter the magnet at the south pole and pass through it to the north pole, thus completing the path. This path forms the magnetic circuit, and each of the lines of force completes it without crossing or combining with any one of the others in the field. A line of force always forms a closed loop so that as many lines enter the south pole as leave the north.

To make a magnet of a steel bar, place the bar flat on a table. Take the south pole of a magnet and stroke the bar with it several times, always from end to end in the same direction. The end of the bar first touched will then become a south pole and the end where magnet last touched a north pole. The bar will then be a magnet. Or wind a few turns of insulated wire around the bar and pass a current of electricity through the wire for a short time, gently tapping the bar with a hammer while the current is flowing. Upon removing the bar from the coil it will be found to be a magnet.

If a piece of iron, mounted on a pivot so it is free to swing about, be placed in a magnetic field of force, the iron will move so that the greatest number of lines of force of the field will pass through it. If the movable body be a magnet, for example, a compass, it will turn, under the influence of the field, so that not only the greatest number of lines of force will pass through it, but also so that its own lines of force will be in the same direction as those of the field. Upon this fact is based the construction of many forms of electrical instruments.

If a bar of soft iron be placed in the field of a bar magnet, we will find on testing the soft iron bar that it, too, has become a magnet having two distinct poles. The iron bar is called the body under induction, the magnet the inducing body, and this phenomenon magnetic induction. Magnetic induction is defined as the action and reaction which occur when a magnetic field makes a magnet of a body placed therein.

Electromagnetism.

Every wire through which a current flows possesses a magnetic field around it. This fact can be proved by bringing a compass near it. The magnetic field will act on the compass, and the needle will be deflected, showing not only the presence of a magnetic field but also the direction of the lines of force. These will be found to encircle the wire, always running from left to right, similar to the direction in which the hands of a clock move, assuming that the current is flowing directly away from the observer.

A solenoid consists of one or more layers of wire wound on a spool, usually of nonmagnetic material, the length being great as compared with the diameter. A magnet can be made of a solenoid by passing a current of electricity through the wire. One end of the coil will be the north pole and the other the south pole. If an iron bar be placed lengthwise through the coil while the current is flowing, it will be found that the magnetism has been increased. This is due to the fact that lines of force are much more easily set up in iron or steel than in a nonmagnetic medium. A solenoid with such an iron core constitutes an electromagnet. The current's magnetic field induces magnetism in a piece of iron placed within its limits.

If the iron core of a solenoid is pulled out while the current is flowing the attractive force of the solenoid will tend to pull the core back until its middle point coincides with that of the solenoid. This principle is made use of in many electrical devices, such as circuit breakers, ammeters, and telautographs. Electromagnets are used in many kinds of instruments—electric bells, telegraph sounders, telephone receivers, and relays are some examples. The strength of any electromagnet depends on the number of turns of wire and the strength of current passing through it.

Electromagnetic Induction.

If a straight wire be moved across a magnetic field so as to cut lines of force, a difference of potential will be set up between its ends. If the ends of the wire be connected outside the field, a current will flow. This is called electromagnetic induction, and the currents so produced are induced currents. Upon the principle of magnetic induction is based the operation of all dynamos, transformers, induction coils, telephones, etc.

No distinction is made between the magnetic field of a permanent steel magnet and that of an electromagnet. Either the magnetic field or the closed circuit may be moved so long as the lines of magnetic force are made to cut the wire of the closed circuit. Usually a coil of wire with an iron core (electromagnet) is used to produce the induction. It is called then the primary coil, or simply "primary." The closed circuit, or the circuit under induction, is then called the secondary coil, or "secondary."

Current may be induced in the secondary by any of the following methods:

1. By moving either the primary or secondary while current is flowing in the primary.
2. By making or breaking the primary circuit.
3. By altering the current in the primary.
4. By reversing the direction of current in the primary.
5. By moving the iron core while current flows in the primary.

Electrostatic Induction.

It has been found that an insulated conductor, such as a sheet of tin, an aerial-line wire, or a cable conductor, has the property of receiving an electrostatic charge when subjected to an electromotive force. If, for instance, a conductor of the type mentioned above be thoroughly insulated and one terminal connected to one side of a battery, the other side of which is grounded, a certain amount of electricity will flow into the conductor and appear upon its surface as an electrostatic charge, and the potential of the conductor will be raised to that of the battery. The conductor in this condition is said to be charged and holds an amount of electricity depending upon its capacity. The charge is of the same polarity as the terminal of the battery to which the conductor is connected.

Experiment has determined that a charge can not exist on a conductor except there be an equal and opposite charge induced upon the bodies surrounding it, and this second induced charge is always of opposite polarity to that of the first charge. If now the conductor be connected to the ground it will lose its charge, but the charge of opposite sign on the surrounding bodies will still be held, although having no connection with the first body or with the source of electromotive force. This action by which bodies are charged through an insulating medium constitutes electrostratic induction, and the arrangement of two insulated conductors separated by an insulated medium constitutes a condenser. The most common type of condenser is the Leyden jar, in which the insulated conductors are sheets of tin foil, one placed on the outside, the second on the inside of the glass jar, the latter forming the insultating medium or dielectric, as it is commonly called. The capacity of the condenser, or its ability to receive an electric charge, varies in direct proportion to the area of its plates inversely as the square of the distance between the plates and directly as the specific inductive capacity of the dielectric. Where air is used as the dielectric, this latter quantity is unity. The substances, other than air, ordinarily used as dielectrics have a specific inductive capacity of two to three times as great as that of air. Condensers used for telephone purposes where it is necessary to obtain considerable capacity in very limited space are commonly built up of alternate layers of tin foil and paraffined paper tightly pressed, so as to bring the layers of tin foil which comprise the plates as close together as possible. The condenser is very extensively used in telegraph and telephone work as a means of allowing alternating or pulsating currents to pass while preventing the flow of direct currents. This is the direct opposite of the functions of an impedance coil, which imposes a very high resistance to variable currents while offering little resistance to the flow of direct current.

Principle of the Transformer.

An induction coil, or transformer, consists of two independent coils wound on the same iron core and insulated from each other and from the core. Alternating or interrupted currents in one of the coils (called the primary) produce a variable number of lines of magnetic force in the iron core, and thus currents are induced in the other coil (secondary), so that any E. M. F. that may be applied to the primary may be changed to a higher or lower one in the secondary. The ratio of primary to secondary E. M. F. is equal to the ratio of the turns in the two coils. For example, if there are 10 turns in the primary and 100 turns in the secondary, the induced E. M. F. will be 10 times greater than that used in the primary. When a low E. M. F. in the primary is changed to a higher one in the secondary coil, the latter loses in current strength what it gains in pressure. For example, in the above case, if there is 1 ampere current at 10 volts pressure in the primary and the E. M. F. of the secondary is 100 volts, only 0.1 of an ampere of current would be flowing through the latter. This assumes that there are no losses in the transformer. This principle is made use of to generate very high electromotive forces such as are used in wireless telegraphy.

THEORY OF THE TELEPHONE.

In the act of speaking the vocal cords cause air vibrations, which, falling upon the drum of the ear, are recognized by the auditory nerves as speech. If, instead of falling on the eardrum, these vibrations should fall upon a diaphragm which is capable of changing them into electrical vibrations, and there is some means of transmitting them along a line and again reproducing at the other end into similar air vibrations, we have the telephone. In order to understand the action of the telephone it is necessary to define lines of force and explain two simple laws of magnetic induction. Lines of force are imaginary lines which surround a magnet and indicate by their position and number the direction and strength of its action. The laws of magnetic induction referred to are: First, if a number of lines of force thread or pass through a coil of wire and this number is increased or diminished, a momentary current will flow in the coil; second, if a coil of wire be wound around a permanent steel magnet and a current of electricity be sent through the windings, it will, if in a certain direction, increase the strength of the permanent magnet, and if in the opposite direction will diminish its strength. To understand how articulate speech is transmitted by means of the telephone, let us take the simplest case of two telephone receivers, *A* and *B*, connected to the line as shown in figure 3–1.

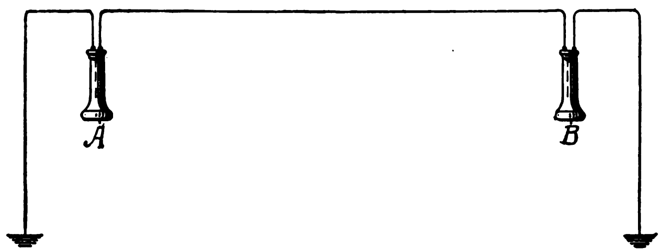


Fig. 3–1.—TELEPHONE CIRCUIT SIMPLIFIED, USING TWO TELEPHONE RECEIVERS.

The telephone receiver (a more detailed description of which will appear later) consists of a soft-iron diaphragm placed close to a permanent magnet. Around the diaphragm end of this magnet is wound a coil of fine insulated copper wire. The air vibrations, caused by the act of speaking, upon striking the iron diaphragm at *A* cause it to vibrate. The vibrations of this diaphragm produce changes in the number of lines of force which thread through the windings of the coil. These changes, according to the first law, produce a current in the winding which will be of greater or less strength and in opposite directions, following the vibrations of the diaphragm. This varying current proceeds along the line, and when it arrives at *B* will increase and diminish the strength of *B's* magnet. The variation of the strength of *B's* magnet will produce a varying pull on *B's* diaphragm and cause it to vibrate in a manner similar to the diaphragm of *A*. The vibration of the diaphragm at *B* is recognized as sound coming from *A*. The simple circuit shown in figure 3–1 would permit a person to talk or hear, as the case may be. The first modification of the circuit (fig. 3–2) is to introduce two telephone receivers at the point *A* and two at the point *B*, all being in series, one serving as the transmitting and the other as the receiving instrument at each point.

For certain reasons this type of receiver just described does not make a good transmitter, and in practice is replaced by a battery transmitter.

A complete local battery telephone instrument consists of a receiver, local battery transmitter, induction coil, magneto generator, call bell, and certain switching devices which are contained in the magneto-generator box.

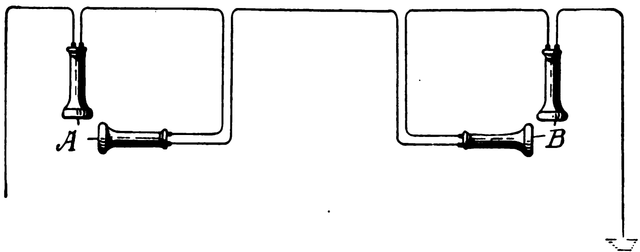


Fig. 3–2.—TELEPHONE CIRCUIT SIMPLIFIED, USING FOUR TELEPHONE RECEIVERS.

A complete common battery instrument consists of a receiver, transmitter, induction coil, condenser, call bell, and hook switch.

LOCAL BATTERY TRANSMISSION.

The battery transmitter depends for its action on the fact that a varying pressure changes the resistance of carbon. The transmitter consists of a num-

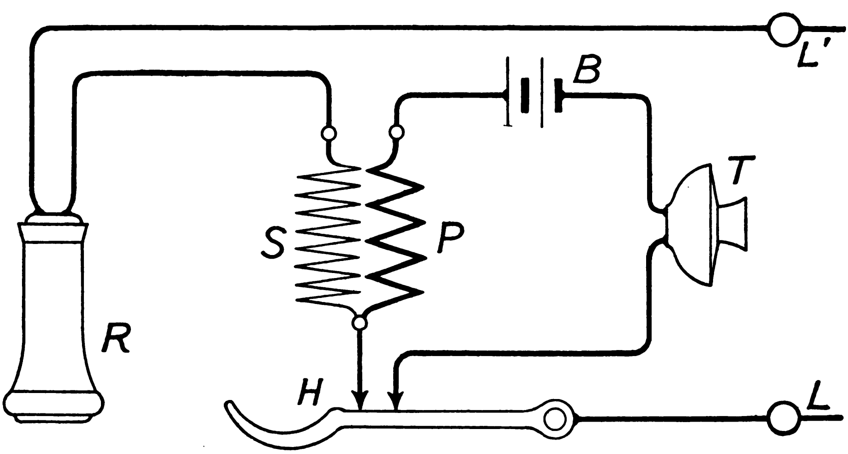


Fig. 3–3.—TELEPHONE CIRCUIT, LOCAL BATTERY, SIMPLIFIED.

ber of carbon particles or granules in a proper receptacle with a means of varying the pressure upon the granules in circuit with a battery and the coarse-wire winding of an induction coil. The induction coil consists of a bundle of soft-iron wires, surrounded by two windings of insulated copper wire, one being of coarse wire, with few turns and low resistance, called the "primary," and the other of fine wire, with a large number of turns and higher resistance, called the "secondary." The relative position of these various parts of a local battery instrument is indicated in figure 3–3, in which *T* is the transmitter that contains the carbon granules through which the current from battery *B* flows. *T* also contains a diaphragm which presses on the carbon granules, or is so connected with them as to vary the pressure between the particles as the sound waves fall on it. *P* is the coarse and *S* the fine wire winding of the induction coil, which is connected to the receiver *R* and the line. The local battery circuit includes *B*, *P*, *H*, and *T*. As the air vibrations fall on the diaphragm at *T* they produce a change in the resistance between the carbon particles in contact with it. This change of resistance causes the current flowing in the coarse-wire coil to fluctuate, thereby inducing an alternating current in the fine-wire coil, which goes to the line and receiver and reproduces speech, as has been explained before.

COMMON BATTERY TRANSMISSION.

The common battery telephone operates similarly to the local battery telephone in its essential details. The principal point of difference lies in the fact that in common battery operation the current which flows through the transmitter is furnished by battery installed at the central exchange in place of local battery installed in the instrument, as in the case of the local battery telephone. In the common battery telephone, battery is supplied over the same wires that are used for transmitting speech. Figure 3–4 shows most of the essential parts of the common battery instrument. The induction coil for this type of instrument is usually provided with primary and secondary windings having more nearly the same number of turns and resistance than is found in the local battery instrument. The receiver and transmitter are practically identical with similar parts of the local battery telephone. The operation of a typical set is as follows (referring to fig. 3–4):

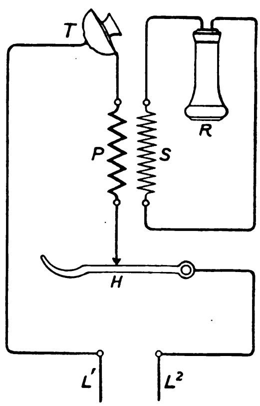


Fig. 3–4.—TELEPHONE CIRCUITS, COMMON BATTERY, SIMPLIFIED.

Direct current from the positive side of the battery at the central exchange enters the instrument over the line L^2, passes through the hook *H*, primary winding *P* of the induction coil, transmitter *T*, and leaves the instrument by the line L^1. If now the transmitter *T* is spoken into, the diaphragm, vibrating, produces a change in the resistance between the carbon particles placed near it.

This varying resistance causes a corresponding variation in the current flowing, which is received at the distant station as speech. This varying current in the winding *P* acting upon the winding *S*, which is placed upon the same core, induces a current in the receiver circuit composed of the receiver *R* and the winding *S*. In the case of receiving from a distant station the voice current may be considered to follow the same course as that taken by the battery current. This current, however, is variable, and in passing through the winding *P* of the induction coil induces a current in the receiver circuit.

In the normal condition of the instrument when not in use the receiver *R* draws down the hook *H*, opening the contact, thus preventing the flow of battery when the instrument is not in use.

Owing to the fact that the common battery instrument depends for its operation on direct current in the line, the range of such operation is necessarily limited by the resistance of the line circuit. When the resistance of the line becomes so high as to materially cut down the strength of current, loudness of voice waves transmitted is correspondingly decreased.

MAGNETO.

The magneto generator is largely used for producing the calling current. It is the simplest form of electric dynamo and consists of an armature wound with many turns of fine wire so mounted as to enable it to be rapidly revolved between the poles of a permanent horseshoe magnet. Its theory depends upon the principle that if the number of lines of force passing through a closed coil be varied a difference of potential will be developed between the terminals of this coil, and if an external circuit be connected electric current will flow, the direction of which will depend upon the relative direction of the lines of force and the movement of the coil.

The following from "Telephonology," by Van Deventer, clearly explains the action of the magneto generator:

A magneto generator is shown in theory in figure 3–5. N. S. represents ends of the permanent magnets. The center opening is known as the "field." In this is placed the revolving armature upon which is wound many turns of insulated wire. The manner in which the current is generated will be understood from a careful study of the figures.

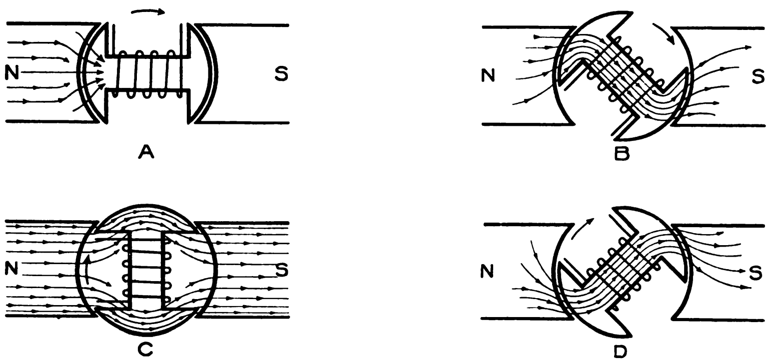


Fig. 3–5.—TELEPHONE MAGNETO GENERATOR, THEORY.

Magnetic lines of force are flowing across the field from the *N* to the *S* pole. To generate a current the wire must move across the lines of force, and in *A* the maximum number of lines are passing through the coil. The number of lines do not change until the armature has passed beyond the position shown in

B and the voltage is 0. A little beyond *B* the lines begin to decrease, and current is generated until *C* is reached, when the remaining lines are shortened out of the coil and the rate of change of the lines is greatest and the voltage is at a maximum. This is the peak or highest point of the wave, shown in figure 3–6.

When the position shown in *D* is reached the lines of force pass through the coil in the opposite direction and the voltage drops to 0. This continues as long as the crank is turned.

While the wire is passing from the position of *A* to that in *B* a plus current, or, as it is termed, a positive current, is generated if the north pole of the magnet is on that side, while from that in *C* to *D* a minus or negative current is generated, because the wire is there subject to the influence of the south pole.

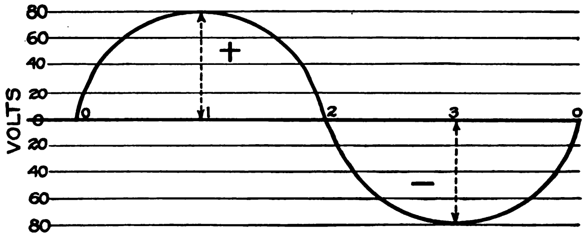


Fig. 3–6.—TELEPHONE MAGNETO, VOLTAGE CURVE.

Plus current is represented by the sign + and minus currents by the sign —. Current flowing first in one direction and then in another is called alternating current, and figure 3–6 illustrates waves of a current of this kind given by a magneto generator. On the left are figures representing the voltage, while the points 0, 1, 2, etc., along the curved lines represent the different positions of the wire during one revolution and correspond to those in figure 3–5. Starting at line 0 where there is no current, we will suppose that the upper curved line represents plus current and the lower curved line minus current. From this it will be seen that current from the telephone generator flows first in one direction and then the other, the voltage increasing from 0 to 1, and then decreasing to 2, as the wire at this point (see *B*, fig. 3–5) is no longer cutting across the lines of force. The current then increases to 3 in the opposite direction (see *C*, fig. 3–5), and again decreases to 0 (*D*, fig. 3–5).

Magneto generators used by the Signal Corps are provided with an automatic device which opens the armature circuit when the armature is at rest.

At the usual rate of turning the magneto generator by hand the voltage will be about 65 to 75 and the frequency about 15 complete cycles, or 30 alternations, per second.

In figure 3–7, *A* shows the generator armature on which are wound the many turns of fine wire which are revolved in the magnetic field referred to above. It will be noted that this armature is made of a large number of thin stamped metal pieces which are assembled on the armature shaft as shown. In part *B* of the above figure the generator armature, wound, has been placed within the generator frame. Contact pieces of the device for closing the generator circuit, mounted in place on end of the generator frame, are shown in the figure. On the other end a gear which meshes with a small pinion on armature shaft and a crank for revolving are shown. When crank is rotated in clockwise direction, the shaft, upon which is mounted the gear, automatically protrudes through end of frame, thereby closing the two contact pieces which automatically open when revolving of crank ceases.

C shows a complete generator of the 5-bar type, with horseshoe magnets in place.

Generators used by the Signal Corps are provided with 3, 4, or 5 bars, depending upon the class of service in which they are to be used.

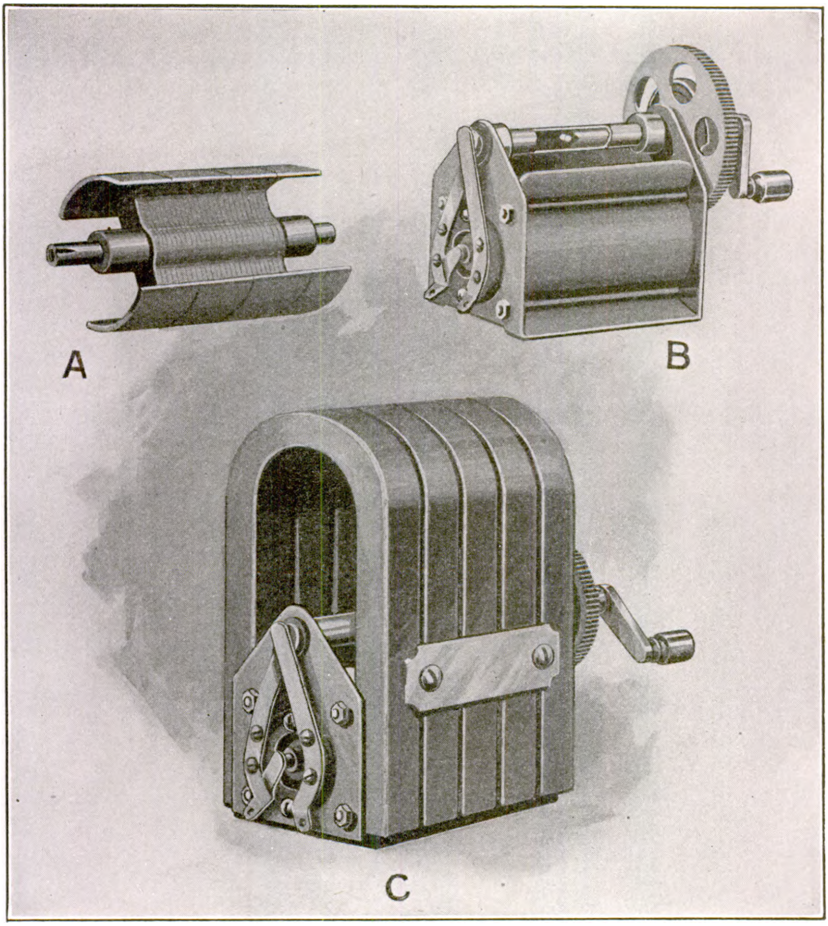


Fig. 3–7.—TELEPHONE, MAGNETO GENERATOR.

Receiver.

A hand receiver of the type now used in the Signal Corps is shown in figure 3–8. It consists of a U-shaped permanent magnet *t*, to the ends of which are fastened soft-iron pole pieces *p p*. Over each pole piece is a coil of fine wire wound on a bobbin with nonmagnetic metal heads. These coils are connected in series in such a manner as to make the front end of one the north pole and the similar end of the other the south pole when current flows through both coils in a certain direction. The combined resistance of these coils connected in series is about 80 ohms. The pole pieces pass through the bottom of a metal cup *C*, which is thus secured firmly in place. The diaphragm *d*, of soft iron, tinned or enameled, rests on the rim of this cup. A clamping ring *f* screws onto the metal cup *C*, thus holding the diaphragm *d* firmly in place. The receiver cords are connected to terminals *m*, a strain cord being attached to the loop of the magnet to provide against injury to the cord conductors. As thus assembled the receiver is operative and may be so used in case of accident to the containing shell and cap. This shell *S* slips over the working parts of the receiver and is held in place by the earpiece *g*, which screws onto the shell. The separation of the diaphragm from the pole piece varies with the different types of receivers, the usual separation being about 0.014 inch.

The operation of the receiver is as follows:

The pole pieces *p p*, being attached to the ends of the permanent magnet *t*, have one a north and the other a south polarity and the magnetic circuit is completed from one pole to the other through the soft iron diaphragm *d*, which is, therefore, drawn toward the poles and held in constant tension. If now a current flows through the coils in such a direction that the lines of force due to it coincide with those of the permanent magnet, the diaphragm will be pulled closer to the pole pieces, due to the increased strength of the magnetic field. If the current flows in the opposite direction, the strength of the magnetic field, due to the permanent magnet, will be reduced and the diaphragm will spring farther from the poles. It will thus be seen that whether the lines of force due to the current in the coils assist or oppose

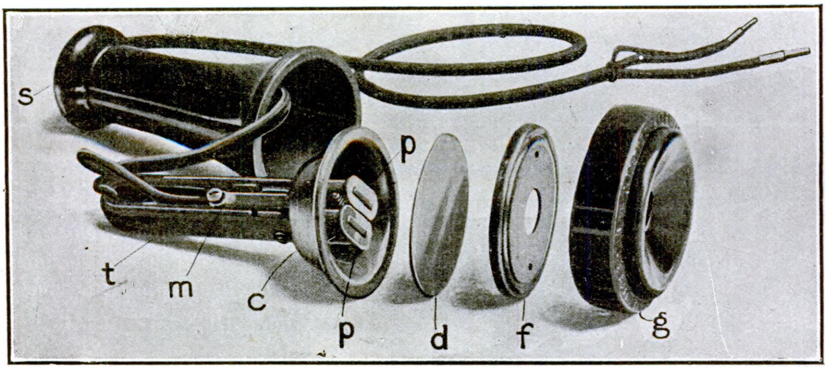


Fig. 3–8.—TELEPHONE HAND RECEIVER.

those due to the permanent magnet, a varying pull is produced on the diaphragm that causes vibrations in the latter in unison with the changes in current. The movement of the diaphragm will thus set up vibrations in the surrounding air which may be perceived as sound.

Transmitter.

The operation of the transmitter depends on the fact that the electrical resistance between two or more bodies, either in light or loose contact, varies with changes in the pressure between the bodies. The change in resistance is due to variation in the area of contact surface between the granules and electrodes and not to compression of the carbon granules themselves. In general, the transmitters used by the Signal Corps depend on this principle. A typical transmitter is shown in figure 3–9. A metal cup, *A*, forms the front electrode and is attached to the diaphragm for sending. The rear electrode is held rigidly in a metal bridge piece, *F*, which is in turn fastened to the frame which supports the mouthpiece *G*, and the remainder of the transmitter. This rear electrode consists of a hard, polished, carbon button, *M*, secured to a brass button between two parts of which is clamped a mica ring or diaphragm, *O*, the outer edge of which is clamped against the front electrode, *A*, by means of a metal ring, *S*, which screws over *A*. The space between the front and rear electrodes is partly filled with hard granular carbon of uniform size. Two dampening springs, *B* and *C*, are provided to prevent vibration of the diaphragm at its natural period.

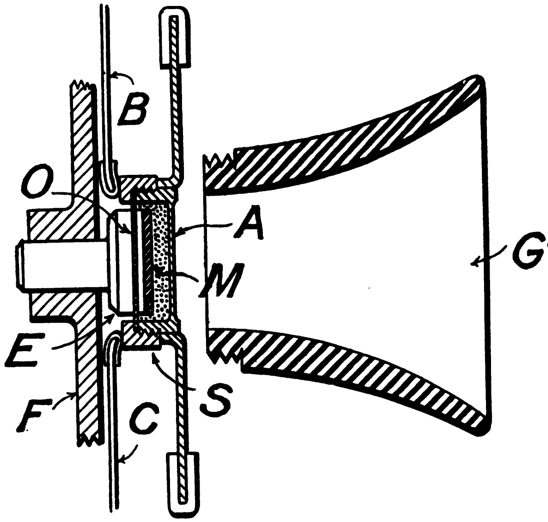


Fig. 3–9.—TELEPHONE TRANSMITTER.

The operation of the transmitter is as follows:

Current from a battery passes from one terminal, *E*, to the carbon electrode through the granular carbon to the metal cup which forms the other electrode. If the transmitter now be spoken into, the diaphragm and cup vibrate in unison with the sound waves produced in the air, thus causing the pressure between the front and rear electrodes on the granular carbon to vary and thus change the resistance of the transmitter. Therefore, variations in the current are set up which correspond exactly with the voice vibrations which reach the transmitter diaphragm.

RINGER.

The magneto generator is commonly used in connection with a polarized bell, or ringer, as it is usually called, by means of which audible signals indicate the incoming calls on the telephone instruments. The usual form of this piece of apparatus is shown in figure 3–10. In this figure *c c* represents soft-iron cores upon which are wound coils of fine wire connected in series with the line wires *l l'*. *N S* is a permanent magnet, and *A* a soft-iron armature pivoted at its center. A slender rod terminating in a small metal ball is attached to the center of the armature. When no current is flowing through the coil the permanent magnet *N S* causes the upper ends of the cores to be north poles and the opposite ends to be south poles. In this condition the armature will be attracted by both cores and will rest against one or the other as may chance to happen. If now current passes through the coils in series in such direction as to increase the strength of the north pole *f*, and to make *e* south pole or weaker north pole, then *f* will attract the end of the armature opposite it, while *e* will repel this end of the armature or attract it with smaller force. If the current is now reversed in direction so that *f* becomes a south pole or a weaker north pole and *e* a stronger north pole, the action will be reversed, *e* will attract its end of the armature and *f* repel its end or attract it with

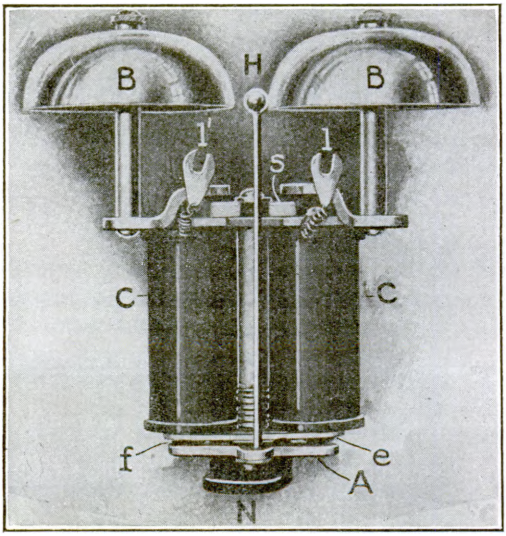


Fig. 3-10.—TELEPHONE RINGER.

smaller force. With the ringer connected to the magneto generator as shown in this figure, the armature will vibrate between the two gongs with the same frequency as the current produced by the hand generator, and a practically continuous ringing sound will result. Practically all of the ringers used by the Signal Corps are wound to a resistance of 1,000 ohms.

Types of Instruments.

The principles upon which depends the operation of the various parts of the telephones have been explained in the preceding pages. The complete circuits of the instruments of the various types used by the Signal Corps will now be considered, and it will be assumed that the operation of the various parts as explained above is understood, and will not be discussed further. The instruments herein described have been selected as being typical of those now in use, and while slight modifications of the circuits shown may be encountered, it is believed that if a person familiarizes himself with these circuits no trouble will be experienced in mastering any which are slightly different.

It will be noted that desk telephones of local battery and common battery types employ precisely the same principles as wall telephones, but that it is necessary to modify circuits and relative positions of component parts in order to meet requirements whereby the ringer (and magneto generator in local battery instruments) are stationary and the transmitter, receiver, and hook switch (as a unit) are movable. To accomplish this, all manufacturers employ the well-known desk stand and ringer box, connecting the two by means of a flexible cord consisting of two or more conductors. Some manufacturers place the induction coil in the ringer box and others in the base of the desk stand.

Circuits of the local battery telephone are as follows, reference being made to figure 3–11.

Being called.—Hook switch contacts shown in diagram as closed would be open, as receiver would not be removed from hook of hook switch. Magneto generator current enters at *L*, to ringer, to *L'*.

Calling distant station.—Hook switch contacts shown in diagram as closed would be open, as receiver would not be removed from hook of hook switch. Revolving crank of magneto generator contact at *C* is closed and circuit is *C* to *L*, through one side of line, to ringer of distant station, through other side of line, *L'* to *A*.

It will be noted that ringer of station calling will also be operated. The reader will bear in mind that the windings of ringers are of high impedance, which, as previously explained, offers a very high resistance to the high frequency alternating currents transmitting the sound waves, and for this reason

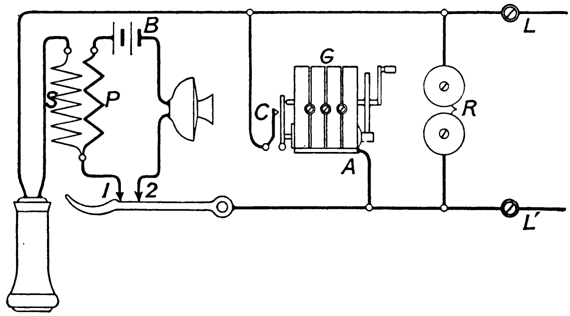


Fig. 3–11.—TELEPHONE, LOCAL BATTERY, CIRCUITS.

they can be connected direct across the line. The magneto generators are capable of operating forcibly under usual line conditions approximately 10 ringers.

Listening.—Hook-switch contacts are closed as shown in diagram as receiver should be removed from hook. A high voltage, high frequency alternating current from distant telephone enters at *L*, passes through receiver, secondary of induction coil, contact 1, hook of hook switch, and *L'*.

Talking.—Hook switch contacts are closed, as shown in diagram, as receiver would be removed from hook. Direct current flows in primary circuit as follows: Battery, transmitter, contact 2, hook of hook switch, contact 1, primary of induction coil. Voice waves fall on diaphragm of transmitter, varying strength of current in primary circuit, thereby inducing in secondary of induction coil a high voltage and high frequency alternating current which is transmitted to distant receiver by means of the following circuit: Secondary of induction coil, contact 1 of hook switch, hook switch, L', one side of line, circuit of distant telephone, other side of line, *L*, receiver, connection to induction coil.

A few commercial standard local battery telephones are shown in figures 3–12 to 3–15, which follow.

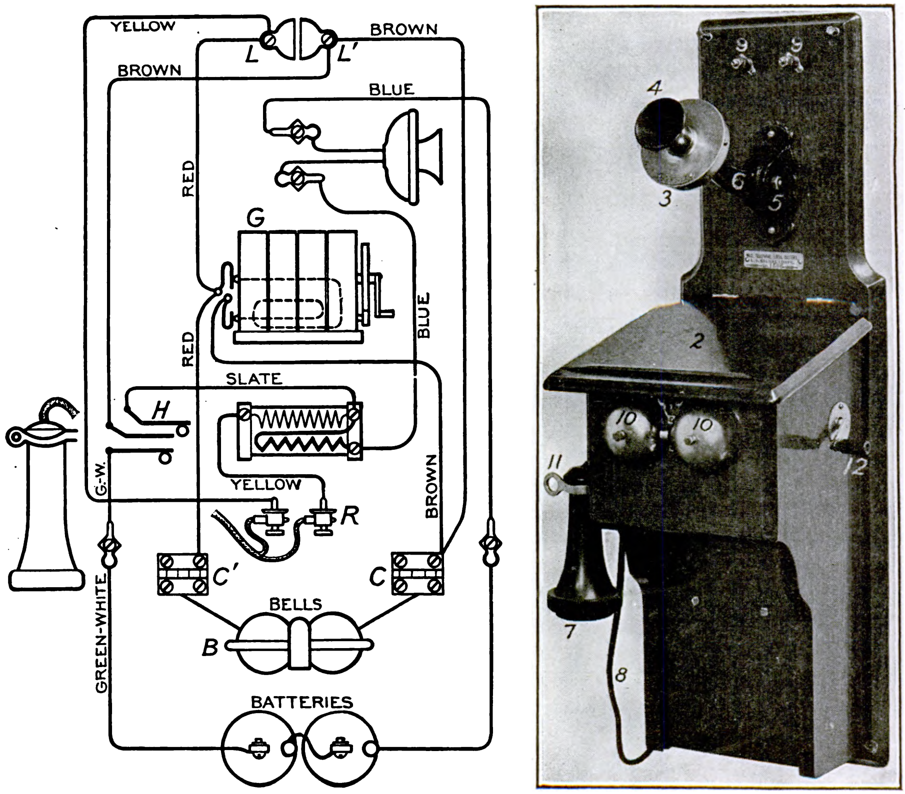


Fig. 3–12.—TELEPHONE, WALL, L. B., SUMTER MFG. CO., AND CIRCUITS.

Part No.	Name.	Reference No.
1	Backboard	1
2	Shelf with hinges	2
3	Transmitter	3
4	Transmitter mouthpiece	4
5	Transmitter bracket	5
6	Transmitter-bracket arm	6
7	Receiver, hand	7
8	Receiver, hand, cord	8
9	Binding post line	9
10	Binding post for receiver cord	
11	Ringer, complete	
12	Ringer, gong for	10
13	Ringer, hammer and armature	
14	Ringer, coil (2 to a set)	
15	Switch, hook, complete	
16	Switch, hook, hook for	11
17	Switch, hook, contact springs	
18	Coil, induction	
19	Magneto, complete	
20	Magneto, crank handle	12
21	Magneto, permanet magnet	
22	Magneto, armature for	
23	Magneto, gear for	
24	Magneto, pinion for	
25	Magneto, contact spring for	

LOCAL BATTERY WALL TELEPHONE.

The circuits of the local battery wall telephone of the Sumter Telephone Manufacturing Co.'s make are shown in figure 3–12.

This figure indicates the actual wiring of the instrument and the parts correctly placed with relation to each other as they are mounted in the instrument. The circuits of this instrument may be traced as follows:

1. Incoming signals enter at line *L'*, pass to hinge *C*, to bell *B*, to hinge *C'*, and return to line *L*. The hook switch is shown in its normal position with the hand receiver in place, all contacts being open.

2. Outgoing signals pass from one pole of the generator *G* to the line *L*, through the distant instrument and return on *L'* to hinge *C*, to the opposite pole of the generator *G*. In this instrument the bells *B* are permanently connected between the lines *L* and *L'*, as is also the generator *G*. The latter, however, by means of its switching device, is open circuited when not in operation.

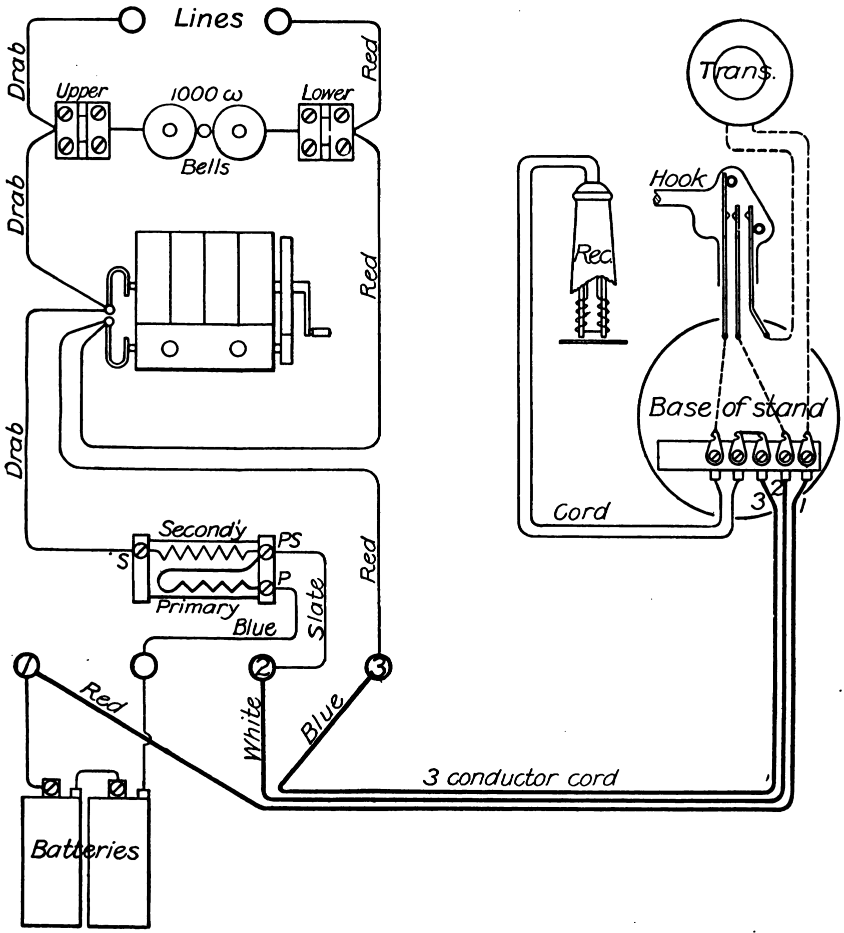


Fig. 3–13.—TELEPHONE, DESK, L. B., SUMTER MFG. CO., CIRCUITS.

3. The local battery and transmitter circuits pass from the battery through the transmitter and the coarse-wire winding of the induction coil through the hook switch *H*, which now has all contacts closed, to the opposite pole of the battery. The receiving circuit passes from *L'* to the hook switch *H*, through the fine-wire winding of the induction coil, through the receiver *R*, to the line *L*.

LOCAL BATTERY DESK SET.

In figure 3–13 is shown circuits of the local battery desk telephone of the Sumter make, as furnished to the Signal Corps. The usual bridging circuit is used. The diagram shows the actual wiring as it is found in the instrument, and the various parts are shown correctly placed with respect to each other.

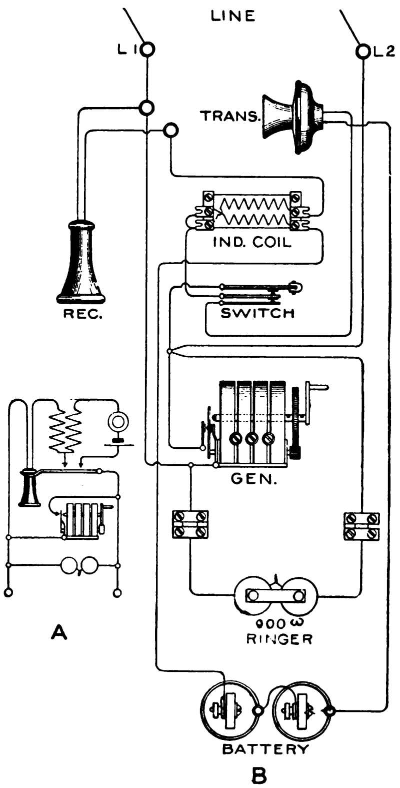


Fig. 3–14.—TELEPHONE, WALL, L. B., GARFORD MFG. CO., CIRCUITS.

The wiring of the Garford local battery wall telephone, which is furnished by the Signal Corps, is shown in figure 3–14. In this figure, *A* shows a simplified circuit, and *B* the wiring as actually found in the instrument with the parts correctly located with respect to each other.

Figure 3–15 shows the Garford local battery desk telephone and the circuits employed with this instrument.

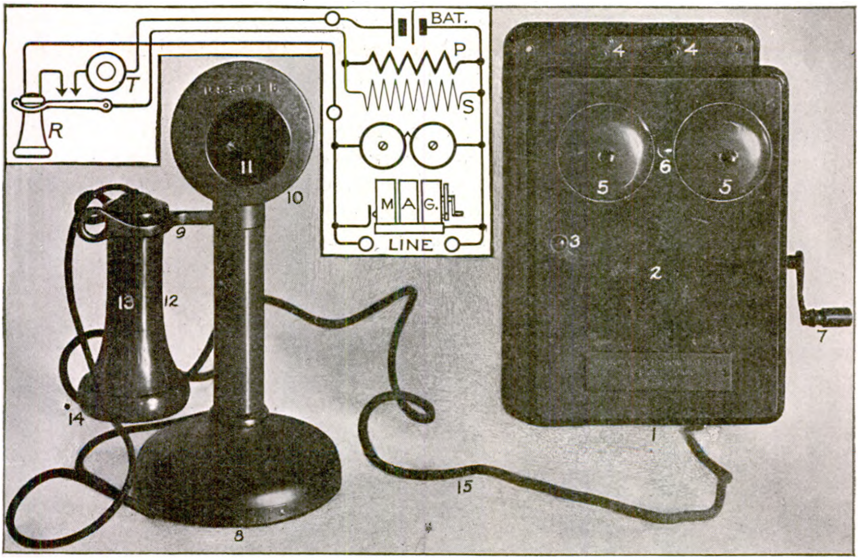


Fig. 3-15.—TELEPHONE, DESK, L. B., GARFORD MFG. CO.

Part No.	Name.	Reference No.
1	Ringer box, complete	1
2	Ringer box, door for	2
3	Ringer box, screw fastener for	3
4	Ringer box, binding post, line	4
5	Ringer box, binding post, main cord	....
6	Ringer, complete	....
7	Ringer, gong for	5
8	Ringer, hammer and armature	6
9	Ringer coil (two to a set)	....
10	Ringer, armature adjusting screw	....
11	Magneto, complete (give number of bars)	....
12	Magneto, crank handle	7
13	Magneto, permanent magnet	....
14	Magneto, armature for	....
15	Magneto, gear for	....
16	Magneto, pinion for	....
17	Magneto, contact spring for	....
18	Coil, induction	....
19	Desk stand, complete with transmitter, receiver, and main cord	8
20	Desk stand, head for	....
21	Desk stand, hook switch	....
22	Desk stand, switch hook	9
23	Desk stand, cord terminal block	....
24	Desk stand, cord terminal block, binding post for	....
25	Transmitter, complete	10
26	Transmitter, mouthpiece for	11
27	Receiver, hand, complete	12
28	Receiver, shell for	13
29	Receiver, cap for	14
30	Cord, main	15

COMMON BATTERY TELEPHONE.

In general it may be said that the parts used in the common battery wall telephones are similar to those used in the local battery.

It will usually be found that the primary of the induction coil used in the common battery instruments is of higher resistance, and that the ratio between the primary and secondary windings of the induction coils are quite different. The distinguishing difference between the commercial local battery telephone and common battery telephone is that the common battery instrument is not equipped with a magneto generator for calling, or batteries for furnishing current for transmitting sound waves, and is equipped with a condenser in series with the ringer. The secondary of induction coil in the local battery telephone is in series with outside line and receiver when receiver is removed from switch hook, while with the common battery instrument under similar conditions the secondary of induction coil is in series with receiver, transmitter, and condenser, the primary of induction coil being in series with transmitter and outside line. By reference to figure 3–16, which shows circuits of the common battery telephone, it will be noted that the paths of both the current in primary of induction coil and current in secondary of induction coil traverse the same line through transmitter. They do not interfere with each other in any way, and the transmitter, being of low ohmic resistance and practically zero impedance, offers comparatively no resistance to either.

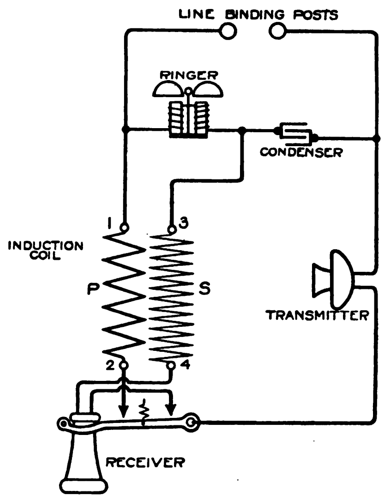


Fig. 3–16.—TELEPHONE, WALL, C. B., WESTERN ELECTRIC CO., CIRCUITS.

The reason for this rearrangement of component parts is due to the fact that battery for furnishing necessary current for operation is remote from location of telephone and is conducted to instrument by means of the line wires. The battery usually consists of 12 or 15 cells of storage battery having a voltage of 24 or 30, respectively.

While the ohmic resistance of the ringer is comparatively high, usually being 1,000 ohms, it will be seen that by connecting this direct across the line a considerable waste of current would ensue, consequently the condenser which opens the direct current circuit is placed in series with the ringer across the line. Another reason for this condenser is that with the commercial common battery telephone the operator at switchboard is signaled by merely removing receiver from hook, thereby closing the direct current circuit through a magnetic device at switchboard. The devices are ordinarily of 200 ohms resistance and operate on approximately 0.01 of an ampere of current, so that by referring to Ohm's law in chapter 1 the reader can readily determine that this signal would be held closed if the 1,000-ohm ringer were connected directly across the ordinary line without condenser in series.

A few commercial standard common battery telephones are shown in figures 3–17 to 3–22 which follow.

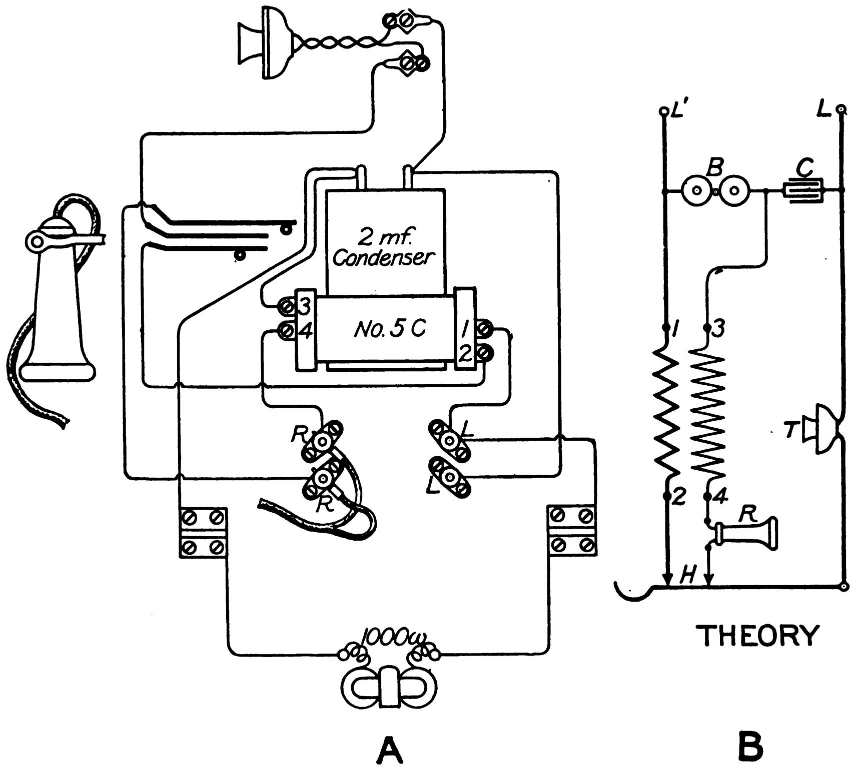


Fig. 3–17.—TELEPHONE, WALL, C. B., SUMTER MFG. CO., CIRCUITS.

The circuits of the common battery wall telephone of the Sumter Manufacturing Co. are shown in figure 3–17. *A* shows the wiring of the instrument and the parts with correct relation to each other, and *B* a simplified circuit diagram of the instrument. The operation of the instrument is as follows:

Assuming that the receiver is in place on the hook switch, the incoming ringing current will pass from the line *L'* through the bells *B*, condenser *C*, to the line *L*, ringing the bells *B*. The hand receiver being removed from the hook switch, the contacts at *H* are closed. In this condition the battery from the central exchange passes from *L'* through the coarse-wire winding of the induction coil, through the transmitter to the line *L*. Battery also passes from the bells *B*, secondary or fine-wire winding of the induction coil, receiver *R*, transmitter *T*, to the line *L*. The resistance of this second path is very much greater than that of the first path, so that the current flowing in this high resistance path may be considered negligible. If now the transmitter be spoken into, the current flowing through the transmitter will vary by reason of the varying resistance of the transmitter caused by varying pressure between the carbon granules. These fluctuations in current result in a fluctuating

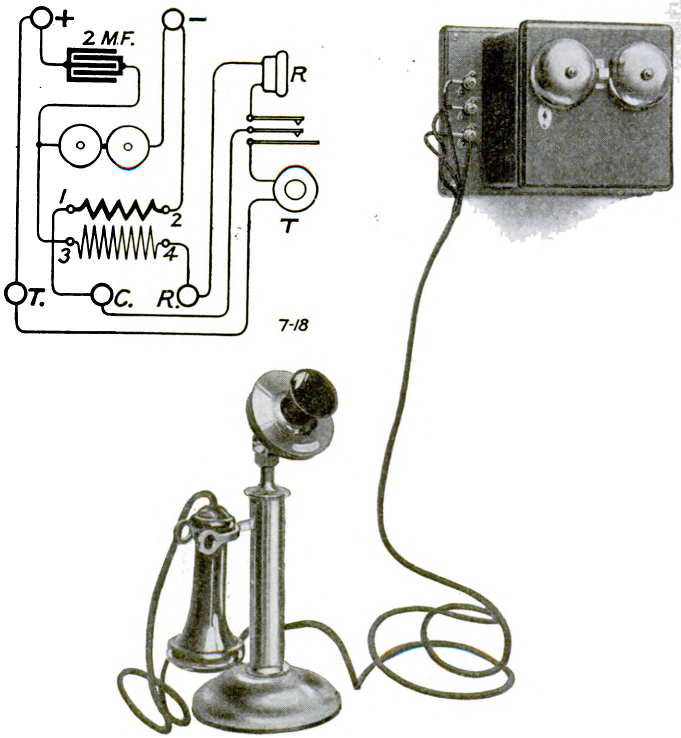
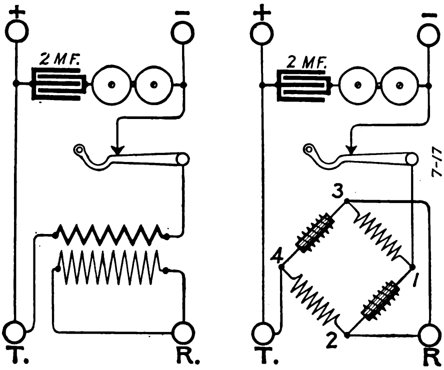


Fig. 3-18.—TELEPHONE, DESK, COMMON BATTERY.

Part No.	Name.	Reference No.
1	Desk stand, complete, with receiver, transmitter, and cord	....
2	Bell box, complete	....
3	Coil, induction	....
4	2 m. f. condenser	....
5	Hook	....
6	Hookswitch, complete	....
7	Receiver, hand	....
8	Receiver, shell for	....
9	Receiver, earcap for	....
10	Receiver diaphragm	....
11	Receiver diaphragm, retaining ring	....
12	Cord, receiver	....
13	Cord, main	....
14	Transmitter	....
15	Transmitter, diaphragm for	....
16	Transmitter, mouthpiece for	....
17	Binding post, line	....



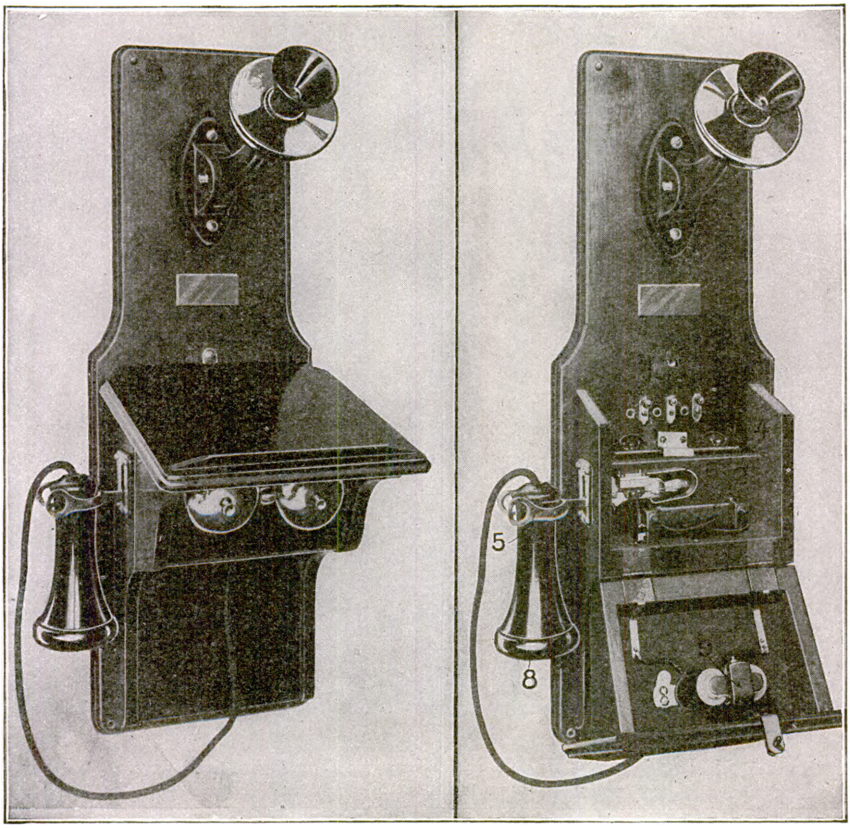


Fig. 3-19.—TELEPHONE, WALL, COMMON BATTERY,

Part No.	Name.	Reference No.	Part No.	Name.	Reference No.
1	Binding post, line....................	1	8	Receiver, shell for.....................	8
2	Coil, induction.........................	2	9	Receiver, earcap for....................	......
3	Coil, induction, terminals............	3	10	Receiver diaphragm,....................	......
4	Condenser...............................	4	11	Receiver, diaphragm, retaining ring..	......
5	Hook......................................	5	12	Receiver, cord for, with terminals....	......
6	Hook, switch, complete...............	......	13	Ringer, complete........................	9
7	Receiver, hand..........................	......			

current in the primary of induction coil in telephone at distant station and induce in the secondary of same induction coil a high-voltage, high-frequency alternating current which affects the receiver, thereby reproducing speech. Incoming speech follows the same circuit as that taken by the battery from the central exchange. This voice current, however, being pulsating in character, induces a current in the fine-wire winding of the induction coil. This current passes through receiver *R*, hook switch, transmitter *T*, and condenser *C*, thus reproducing in the receiver *R* the sounds impressed on some distant transmitter. The condenser also serves to strengthen the effect of the induced current in *R* by reason of the varying potential across its terminals.

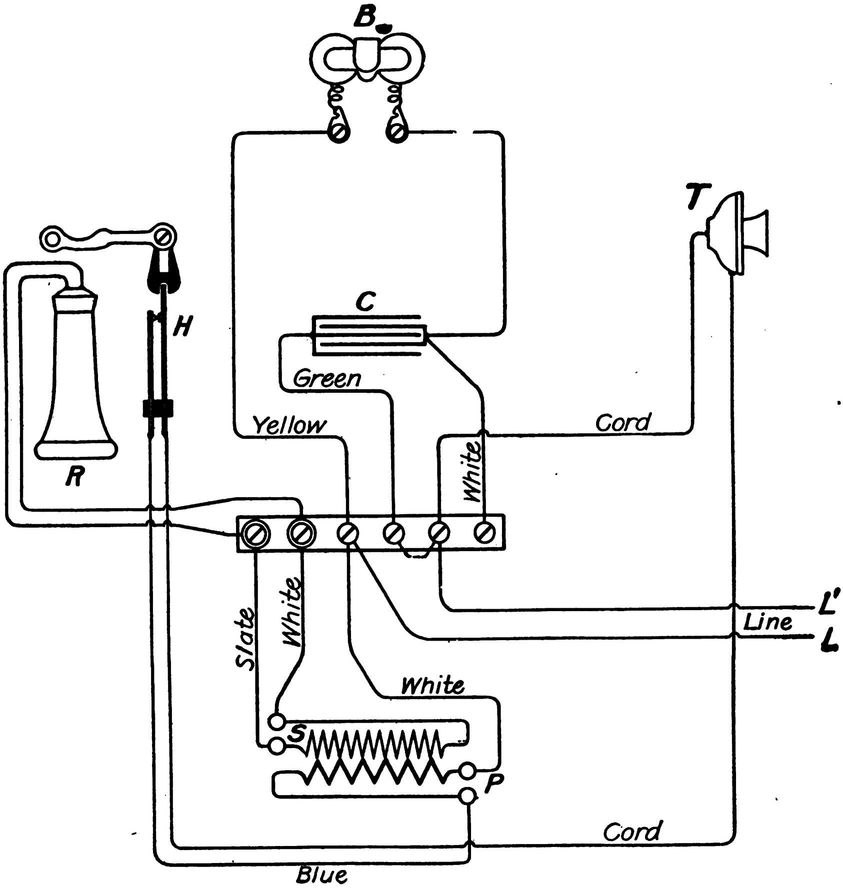


Fig. 3–20.—TELEPHONE, WALL, C. B., N. E. CO., CIRCUITS AS INSTALLED.

Figure 3–18 shows the general arrangement of a common battery desk telephone and figure 3–19 shows the general arrangement of the common battery wall telephone. The circuits shown or modifications of them are used by all manufacturers and the general appearance of the apparatus closely resembles that shown in the illustrations.

Figure 3–20 shows the circuits as installed of a North Electric Co. C. B. wall telephone. Figure 3–21 shows the circuits as furnished in the desk set type of the same instrument.

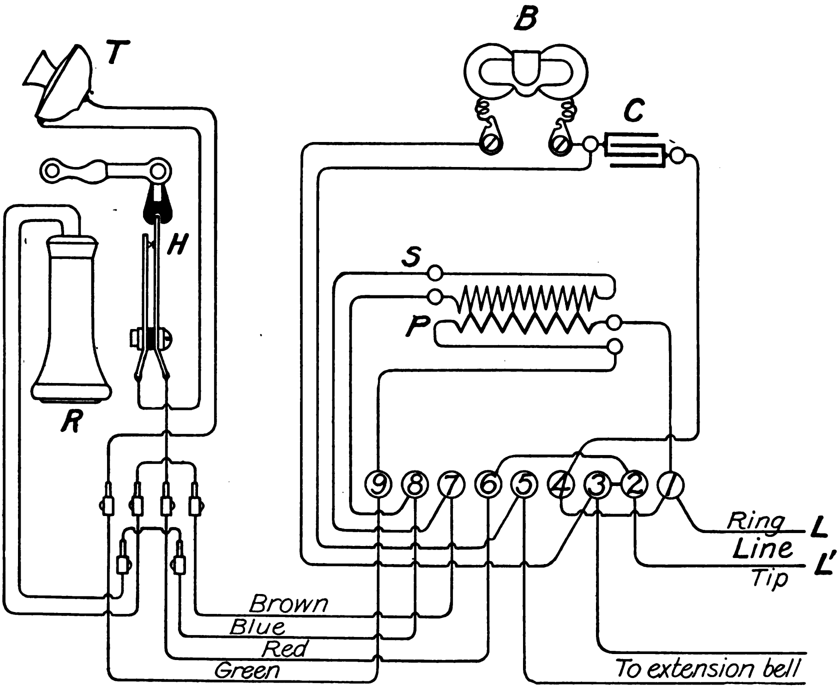


Fig. 3–21.—TELEPHONE, DESK, C. B., N. E. CO., CIRCUITS AS INSTALLED.

Figure 3–22 shows the circuits, as installed, of a common battery desk telephone, having the induction coil located in the base of the desk stand.

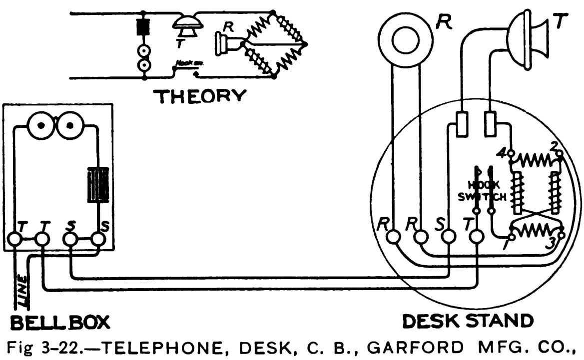


Fig 3–22.—TELEPHONE, DESK, C. B., GARFORD MFG. CO., CIRCUITS AS INSTALLED.

The Camp Telephone.

This telephone, which supersedes the field telephone, was developed by the Signal Corps for use in connection with camp telephone systems and small arms target range systems, and may be installed in tents and structures, or considered a portable instrument for use in the field for testing lines or other purposes.

It is of local battery type. The battery employed is one unit of tungsten type A described in chapter No. 1. Figures 3–23 and 3–24 illustrate this telephone, it being shown dismantled in figure 3–24 to facilitate identification of parts in connection with the preparation of requisitions for renewals.

The first lot of these instruments was equipped with 2-bar magnetos and due to its limitations the instrument could not be used for long-distance work. The new model of this instrument will be equipped with a 3-bar magneto, employing a special high grade steel for permanent magnets, and while in other features there may be a slight deviation from following description, it is believed that figures 3–23 and 3–24 can be used in preparing requisitions, it being merely necessary to state " For Camp Telephone, 3-bar magneto type."

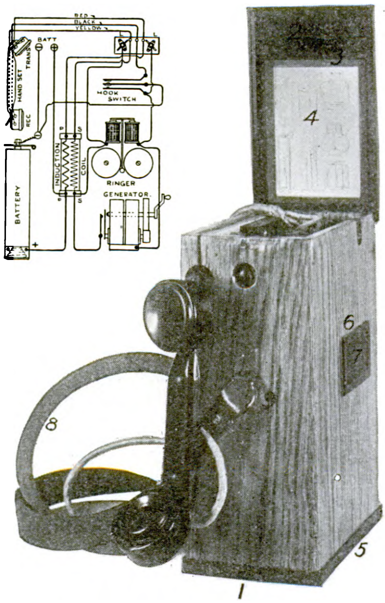


Fig. 3–23.—TELEPHONE, CAMP, AND CIRCUITS.

Part No.	Name.	Reference No.
1	Case complete	1
2	Cover, complete with hinges	2
3	Circuit diagram frame	3
4	Circuit diagram	4
5	Circuit diagram, celluloid cover	
6	Metal base for case	5
7	Wire netting frame complete	6
8	Wire netting	7
9	Carrying strap, complete	8
10	Fitting and ring for carrying strap	9

The instrument is made as compact as practicable and is contained in an oak case 4¼ by 7 by 10 inches high. The top consists of a metal hinged cover with circuit diagram on inside, held rigid when closed by a spring snap which can be readily released by depressing a button. The bottom of case is covered by a flanged piece of metal, the flange projecting approximately one-half inch up sides of case. Through one side of case are six three-eighth inch holes which are covered on the outside by a close mesh metal screen held in place by a metal frame. These apertures are for the purpose of allowing the ringer to be distinctly heard. The case is equipped with a substantial, adjustable carrying strap, each end of which is fastened to case by means of hinged metal rings.

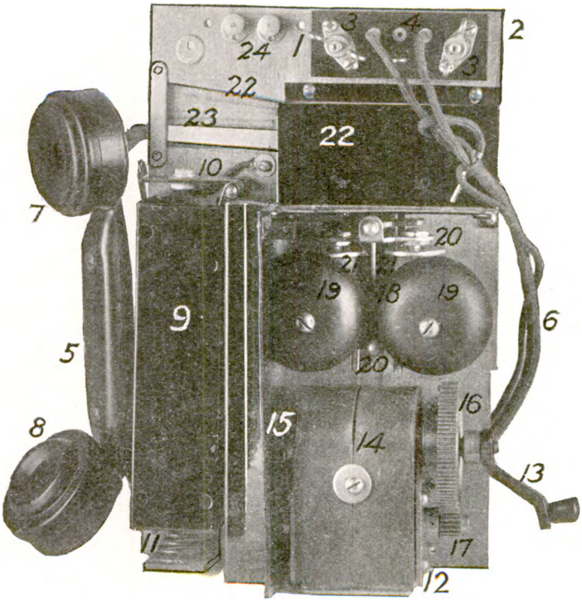


Fig. 3-24.—TELEPHONE, CAMP, DISMANTLED.

Part No.	Name.	Reference No.
1	Base complete	1
2	Connecting block, complete with binding posts	2
3	Binding post complete	3
4	Socket for hand-set cord (3 to a set)	4
5	Hand set complete	5
6	Hand-set cord	6
7	Hand-set receiver	7
8	Hand-set receiver cap	
9	Hand-set transmitter	8
10	Hand-set transmitter cap	
11	Battery case	9
12	Battery-spring catch	10
13	Battery spring and support	11
14	Battery, tungsten, type A (1 unit per set)	
15	Magneto complete	12
16	Magneto, crank handle for	13
17	Magneto, permanent magnet for	14
18	Magneto, contact spring for	15
19	Magneto, armature for	
20	Magneto, gear for	16
21	Magneto, pinion for	17
22	Ringer	18
23	Ringer, gong for	19
24	Ringer, hammer and armature for	20
25	Ringer, coils (2 to a set)	21
26	Ringer, armature adjusting screw	
27	Case for hook switch	22
28	Hook switch, complete	
29	Hook switch, contact springs for	
30	Hook switch, hook for	23
31	Posts, binding, for external battery	24

A small 2-bar magneto generator, small ringer, induction coil, aluminum chamber for the single unit of tungsten type A dry battery, hard rubber block upon which are mounted line binding posts, plug connections for the handset used with the instrument, hook switch and hook operating it and auxiliary battery binding posts are all mounted on a common base which may be readily removed from case after removing magneto generator crank, metal housing for it and three screws which extend through the case.

The instrument may be operated with cover closed which is highly advantageous in inclement weather. To accomplish this there is a suitable opening for leading out the 3-conductor cord to receiver and transmitter, the two latter being mounted in the form of a unit, termed a handset. This handset consists of a transmitter and receiver mounted on a metal piece and is so designed that when the transmitter is normally placed to the mouth, the receiver is automatically adjusted to the ear.

The hook of hook switch is so designed that it protrudes through case. When it is desired to transport the instrument or to remove the base upon which is mounted all the parts of the instrument, it is merely necessary to depress the hook and push it toward the base. By this arrangement the hook is not only held in the down position, thereby opening the battery circuit, but it is also protected.

The aluminum chamber for housing the single unit of tungsten type A battery is equipped with a spring catch so located that when upper hinged piece is depressed to proper position, the battery compresses a helical spring, thereby insuring continual contact. The base is equipped with two screw binding posts which may be used to conect leads to an outside battery in the event of there being no tungsten type A batteries available.

An aluminum frame which is supported on the base previously mentioned forms a compartment for the handset when instrument is being transported. When the instrument is installed for a temporary period, unless in actual operation, the proper place for the handset is hanging on the hook of hook switch, there being a ring on the handset for this purpose.

A small screw driver which will fit practically all the screws used in the construction of the instrument is supported by the metal frame and is furnished with each instrument. The instrument complete weighs approximately 11 pounds.

THE SERVICE BUZZER.

The buzzer is strictly a portable instrument and is issued to troops in the field for use in connection with all kinds of lines of communication. It may be used as a telephone or for sending customary Morse or Continental Code signals and for that reason it is specially adapted for field use.

When it becomes impracticable to transmit messages telephonically, due to line becoming impaired or for other reasons, the usual telegraphic signals can be transmitted and are received in distant telephone receivers in the form of a high-pitched hum, somewhat similar to radiotelegraphic signals. These signals have been exchanged between two of these instruments after the line wire had been severed, both the ends, however, being slightly grounded.

The service buzzer, which is the latest approved instrument of this type of apparatus, replaces the field buzzer, the cavalry buzzer, and the field artillery telephone and hereafter is the standard issue where the above-enumerated obsolete apparatus is involved.

In the first part of this chapter is explained how a circuit of high E. M. F. is obtained by means of two coils of wire wound on a soft iron core in connection with the telephone. This method may be termed mutual induction and is employed in the *service buzzer*. A high E. M. F. can be obtained by means of one coil of wire wound on a soft iron core, the latter method being termed self-induction. In order that operation of service buzzer may be clearly understood, the theory of the field buzzer will first be explained.

The principle upon which the original *field buzzer* operates depends upon the effects of self-induction; i. e., the comparatively high self-induced voltage developed at the terminals of an electromagnet (coil with iron core) when the current through the circuit is suddenly interrupted. The interruptions are automatically produced by a circuit breaker, which is described later. During the interval of time required for the current to reach its maximum value, the field of force expands in direct proportion to the current strength until it also reaches maximum value. The current strength being kept constant, the magnetic field is of constant value. Any variation in current strength produces a corresponding variation in the strength of the magnetic field; therefore, when the circuit is broken and the current rapidly falls to zero the field of force also collapses and disappears. The energy furnished by the current and stored up in the magnetic field is thus returned to the circuit and tends to sustain the original current, as is noticed by a bright spark appearing at point of break.

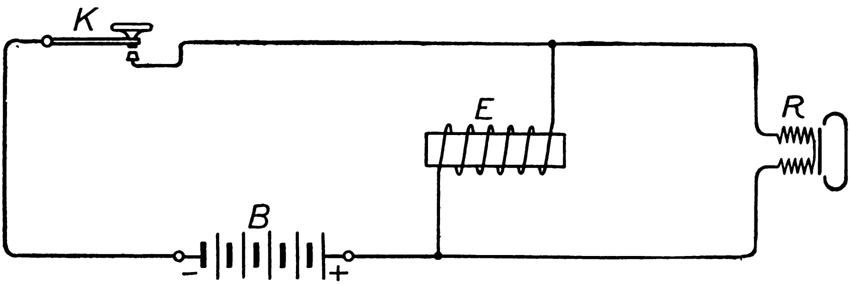


Fig. 3–25.—BUZZER, FIELD, SIMPLIFIED CIRCUIT.

On "make," then, the whirls spring out from and cut the wire, inducing therein a current opposed in direction to inducing current. On "break" the whirls collapse, again cutting the wire and inducing therein a current having same direction as inducing current. The phenomena resulting from such cutting of a wire by magnetic lines of force is called self-induction.

When the circuit contains a coil, the above-noted effects of self-induction are much greater. If the coil contains an iron core the effects of self-induction are still more pronounced.

To make clear the action of the buzzer, let us consider the diagram (fig. 3–25):

B is a battery of five dry cells; *K* is a key for making and breaking the circuit; *E* an electromagnet; *R* a telephone receiver.

When the key is closed there is a rush of current which reaches its maximum strength almost instantly. Simultaneously there is built up a magnetic field of force around the electromagnet. Now, if the key be opened, a pronounced click, of momentary duration, is heard in the receiver, which is caused by a self-induced current of high E. M. F. produced by the collapse of the magnetic field around the coil. This induced current would spark across break at the key if there were not an alternate complete circuit through the receiver.

The more rapidly the circuit is made and broken by closing and opening the key, the greater the rapidity with which clicks in telephone follow one another, until, if the interruptions recur sufficiently often, the sounds in the receiver appear to be almost continuous.

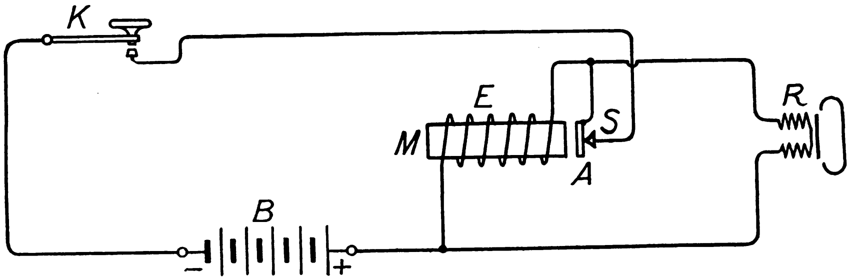


Fig. 3-26.—BUZZER, FIELD, SIMPLIFIED CIRCUIT WITH INTERRUPTER.

If we introduce an automatic interrupter into the circuit (fig. 3–26), a loud buzzing sound is heard in the receiver whenever the key is closed, and the dot and dash of the Morse alphabet are thereby produced by making short and long contacts with key.

The action of the interrupter or circuit breaker is as follows:

When the circuit is made by closing the key *K*, the current flows through coils of the electromagnet *E*, magnetizing the iron core *M*, which, in turn, attracts armature *A*. As soon as the armature is withdrawn from contact *S* the circuit is broken; as a result, the core becomes demagnetized and armature *A* springs back against *S*, thus again closing the circuit. This action continues so long as key *K* is kept closed.

If instead of interrupter we substitute therefor a transmitter (fig. 3–27), then when the key is closed current flows from + side of the battery through the coil to the lower disk (stationary) of transmitter, through loosely packed carbon granules to upper disk (movable) which is attached to the diaphragm, to key, to — side of battery.

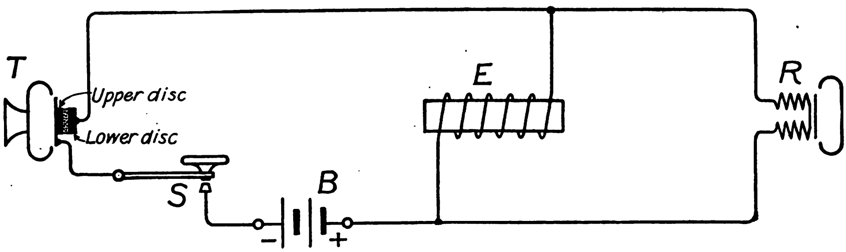


Fig. 3–27.—BUZZER, FIELD, SIMPLIFIED CIRCUIT WITH TRANSMITTER.

Except when this circuit is first made, there is no evidence of self-induction in the circuit until the transmitter is spoken into, then the sound waves of the voice striking the diaphragm cause it to vibrate. The carbon granules between the carbon disks are thus subjected to varying pressure; this causes a variable resistance in the circuit, and the resulting current is a pulsating one (uniform in direction, but varying in strength). The effect of the varying current passing through the circuit is to increase and decrease the field of force built up around the wire. This changing field of force in turn produces the effects of self-induction, and these effects are particularly noticable in coil *E*.

The inductive property of the coil is thus employed to augment the compartively weak primary current to one of high E. M. F., which intensifies the vibration of the receiver diaphragm, these vibrations being received by the ear as articulate speech.

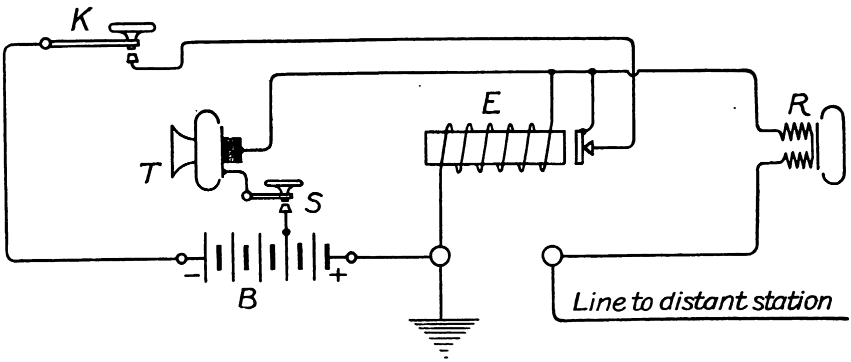


Fig. 3–28.—BUZZER, FIELD, SIMPLIFIED CIRCUIT WITH TRANSMITTER AND INTERRUPTER.

The sounds thus produced are not as loud as those produced by the interrupter even though the same number of cells are used, for the reason that in the latter case the current is completely interrupted (circuit broken), whereas in the case of the talking circuit, current is always flowing, but is varied in strength; therefore the resulting field of force never reduces to zero, the cutting of the wire is consequently less, and the effects of self-induction are diminished.

If we now combine the two circuits described above in one diagram we have the simplified buzzer diagram which is shown in (fig. 3–28).

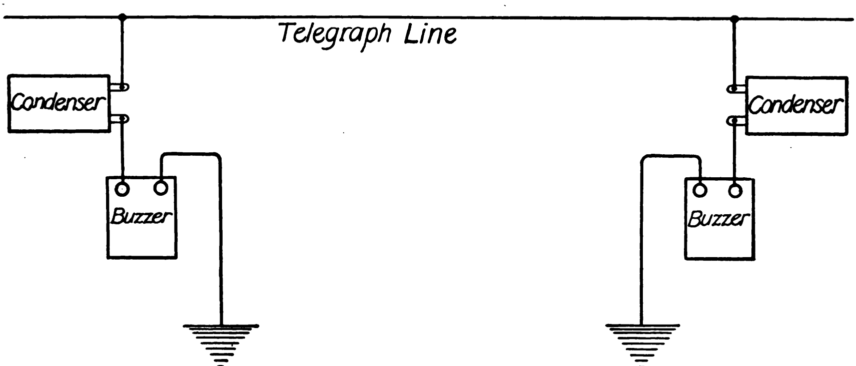


Fig. 3–29.—BUZZERS, CONNECTED TO A TELEGRAPH LINE.

An examination of this figure shows that the only change made is the introduction of two terminal binding posts, one of which is connected to the line, the other to the ground. If a similar instrument is connected at the distant stations, the currents traversing home receiver also pass through distant receiver.

The utilization of existing telegraph lines as a part or the whole of a circuit for buzzer and telephone working, at the same time not interfering with the use of the wire for Morse working, may be effected by using condensers interposed between the line and the buzzer. (See fig. 3-29.)

The pulsations of the ordinary Morse sending are comparatively slow. The condensers, therefore, act as a very large resistance, and no appreciable effect will be noticed in the telegraph line.

The very rapid pulsations produced by the buzzer or transmitter, however, will permit of transmission from one buzzer to the other with little diminution of sound.

Figure 3-30 shows the circuits of the service buzzer. It will be noted that with the field buzzer if a line of low insulation resistance is utilized a heavy drain on the battery will ensue, due to battery being connected to the line, while with the service buzzer under like conditions a heavy drain will not exist, due to battery being connected in a local circuit which does not physically connect with line. It will also be noted that a condenser which can be cut out by means of a short-circuiting switch is contained in the instrument and connected in series with the line. This condenser is for use when it is desired to use an existing telegraph line. (See fig. 3-29.) Two units of tungsten type A dry battery are used with the service buzzer for furnishing the necessary primary current, both being in circuit when sending telegraphic signals, and one only being in transmitter circuit for telephone communication.

The circuits of the service buzzer may be classed as follows:

Primary sending circuit—telegraph.
Secondary sending circuit—telegraph.
Receiving circuit—telegraph.
Primary sending circuit—telephone.
Secondary sending circuit—telephone.
Receiving circuit—telephone.

These circuits may be traced as follows, reference being made to figure 3-30:

PRIMARY SENDING CIRCUIT—TELEGRAPH.

S. P. D. T. knife switch marked "*Sw*" must be closed on side marked "buzzer." Upon depressing key *K*, circuit is as follows: Positive end of battery, through primary of induction coil, to *A* to *B*, contact 1 of key, lever of key, contact 2, vibrator, to negative end of battery.

SECONDARY SENDING CIRCUIT—TELEGRAPH.

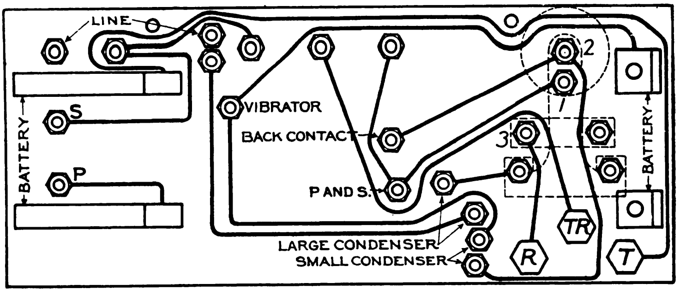
S. P. D. T. knife switch marked "*Sw*" is closed on side marked "buzzer." An A. C. current of high E. M. F. is induced in secondary winding of induction coil by interrupted current in primary and its path is as follows: *G*, earth or one side of line (if metallic circuit is used); "receiving circuit, telegraph" of distant buzzer, other side of line, *L*, contact 1 of key (key is depressed), *B*, *A*, other side of secondary winding of induction coil.

RECEIVING CIRCUIT—TELEGRAPH.

S. P. D. T. knife switch marked "*Sw*" is closed on side marked "buzzer." A. C. current of high E. M. F. reaches *L* from distant instrument by one side of line, contact 3 of key (key raised), receiver, *C*, switch marked "*Sw*," *G*, other side of line to distant instrument.

PRIMARY SENDING CIRCUIT—TELEPHONE.

S. P. D. T. knife switch marked "*Sw*" is closed on side marked "talk"; from positive end of battery through primary winding of induction coil, to *A*, to *B*, through blade of switch marked "*Sw*" to *C*, through push-button switch marked "*PB*," through transmitter to negative side of one unit of the tungsten type A battery.



BOTTOM VIEW OF BACKBOARD SHOWING WIRING

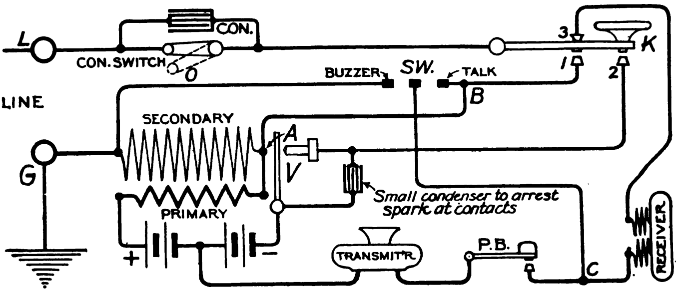


Fig. 3-30.—BUZZER, SERVICE, CIRCUITS.

SECONDARY SENDING CIRCUIT—TELEPHONE.

S. P. D. T. knife switch marked "*Sw*" is closed on side marked "talk." When sound waves fall upon diaphragm of transmitter, an alternating current of high E. M. F. is induced in secondary winding of induction coil. Starting with secondary of induction coil, to *G*, to earth or one side of line (if metallic circuit be used), through "receiving-circuit-telephone" of distant instrument, returning on other side of line, to *L*, through contact 3 of key marked "*K*" (key raised), to receiver, to *C*, to switch marked "*Sw*," through blade of this switch to *B*, to *A*, to other side of secondary winding of induction coil.

RECEIVING CIRCUIT—TELEPHONE.

S. P. D. T. knife switch marked "*Sw*" is closed on side marked "talk." An alternating current of high E. M. F. induced in the secondary winding of induction coil in distant instrument, reaches buzzer over outside line, to *L*, thence to contact 3 of key marked "*K*," to receiver, to *C*, to switch marked "*Sw*", through blade of this switch to *B*, to *A*, through secondary winding of induction coil to *G*, to earth or line (if metallic circuit be used), to distant buzzer.

When an existing telegraph line is utilized, the switch marked "*con sw*" should be thrown to the "O" position in order that the condenser "*Con*" will be placed in the circuit.

The service buzzer is shown in accompanying figures 3–31 and 3–32, it being shown dismantled in figure 3–32 to facilitate preparation of requisitions for renewal parts.

The instrument is contained in an aluminum case fitted with a hinged cover, both of which are covered externally with a russet-colored, smooth-finish leather which is neatly sewed and riveted in place. The overall outside dimensions of the case are approximately 3¾ by 5¼ by 7½ inches. The two units of Tungsten type A battery are contained in a chamber located in the bottom and are accessible without opening main cover, there being an additional small hinged cover in one end of case which is fastened securely, when closed, by a substantial spring clip, and by a flap of leather.

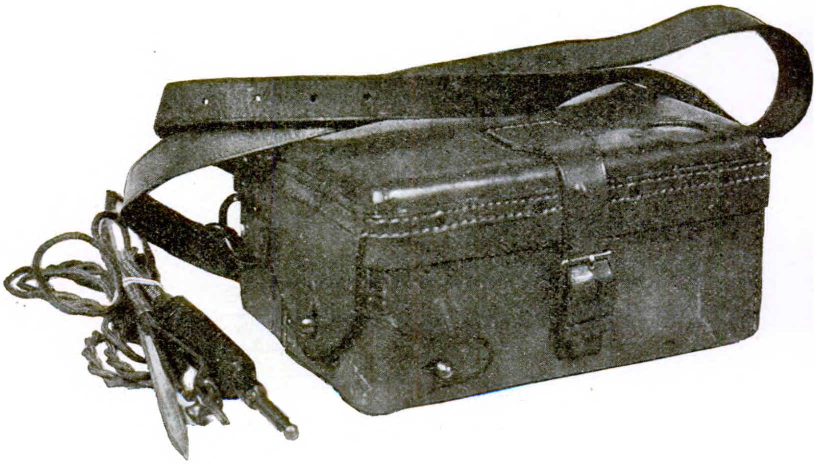


Fig. 3–31.—BUZZER, SERVICE.

The instrument may be operated with both covers closed, which is highly advantageous in inclement weather. To accomplish this there is a suitable opening for leading out the cords to receiver and transmitter, and in main cover, directly over the sending key, is a round aperture which is made moisture-proof by means of a covering of extremely flexible pigskin. The sending key can be readily operated through this flexible pigskin.

The sending key, induction coil, condensers, plug jack, transfer switch, vibrator, and binding posts for transmitter and receiver cords are mounted upon a common base of hard rubber. Wiring to the component parts is routed in the underside of this base, which is mounted in the front of the case above the battery chamber previously mentioned. In the rear of the instrument is a compartment of leather for containing the transmitter, receiver, and cord for connecting them. At one end of this chamber, neatly mounted on a hard rubber strip, is a socket wrench for adjusting the nuts which secure the transmitter and receiver terminals, also two screw drivers—one large and one small—which are so constructed that the shanks may be inserted in the end of socket wrench, thereby using socket wrench as a handle.

Invariably there is furnished with this instrument a two-conductor cord, approximately 5 feet long, one end of which is equipped with a substantial plug similar to those used in connection with telephone switchboards. At other end one of the conductors is equipped with a Williams test clamp for connection to line, the other conductor being equipped with a Signal Corps type D ground rod. The Williams test clamp is so constructed that to attach to line, it is merely necessary to compress the two principal parts, releasing them when line has been inserted in space provided. One side of this clamp is equipped with an 11-point stud securely threaded to test clamp. These points make excellent contact on line, regardless of whether the line be insulated or not. By this means a quick connection can be made to buzzer wire or field wire which is insulated, and when the clamp is removed the abrasion to insulation is negligible. There is an opening in the case of buzzer through which the plug is inserted when connection is desired, and when plug is so inserted, it makes a positive connection by means of a substantial jack mounted on the base as previously indicated.

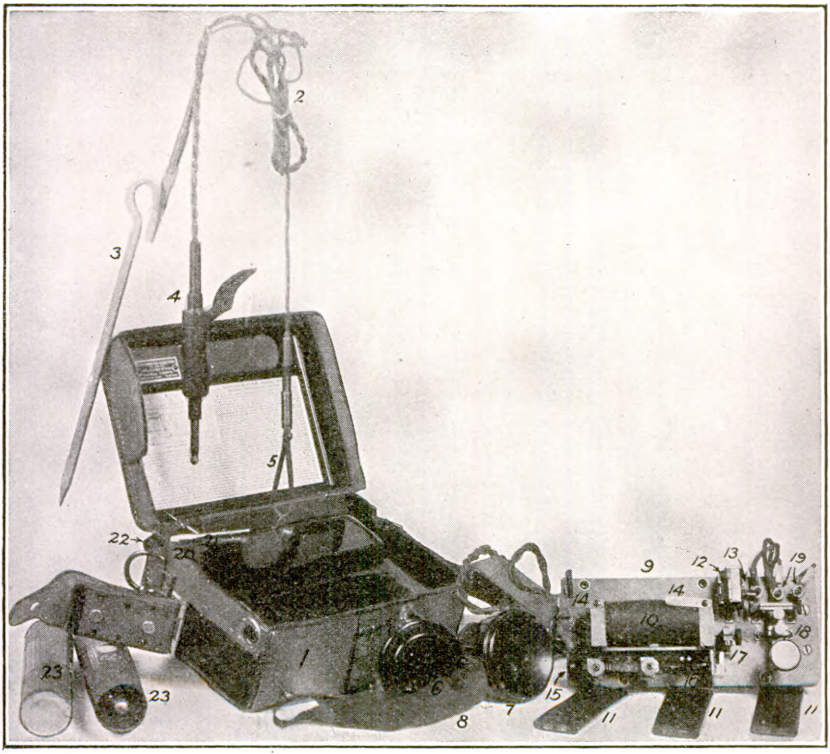


Fig. 3-32.—BUZZER, SERVICE, DISMANTLED.

Part No.	Name.	Reference No.
1	Case, complete	1
2	Cover for case, complete	....
3	Door, battery, complete with hinges	....
4	Case, leather, for transmitter and receiver	....
5	Carrying strap	....
6	Main cord with terminals	2
7	Ground rod, type D	3
8	Plug	4

(Continued on next page.)

Parts list—Continued.

Part No.	Name.	Reference No.
9	Plug, fiber cups for	
10	Connector, type A	5
11	Transmitter	6
12	Transmitter, cap for	
13	Receiver	7
14	Receiver, cap for	
15	Head band, complete	8
16	Base	9
17	Base, holding screws for	
18	Induction coil, complete	10
19	Condensers (3 to a set)	11
20	Condensers, connecting blocks for	12
21	Condensers, short-circuit switch, complete	13
22	Condensers, holding clip	14
23	Jack, plug, complete	15
24	Jack, spring for	
25	Switch, transfer, complete	16
26	Vibrator, complete (11 pieces)	17
27	Vibrator screw, clamp	
28	Vibrator screw, contact	
29	Vibrator tongue with platinum contact	
30	Key, sending, complete	18
31	Key, lever for, without button	
32	Key, supports and screws	
33	Key, spring for	
34	Key, adjusting screw for	
35	Key, hard rubber button for	
36	Binding post, complete	19
37	Binding post, screws and washers for	
38	Screw driver, large	20
39	Screw driver, small	21
40	Handle for screw drivers, and wrench	22
41	Battery, Tungsten, type A (2 units to a set)	23
42	Battery spring and support	

The case has an adjustable carrying strap, one end of which is equipped with a snap connection, the other end being sewed to hinged fitting on case. The instrument, including carrying strap, type D ground rod, Williams test clamp, plug and 5-foot cord, weighs approximately 5 pounds, and full directions for operation, together with a circuit diagram, are attached to the inside of main cover.

Figure 3–33 shows the circuits employed in sending and receiving Morse signals by means of service buzzers. It will be noted that a single conductor is used to connect the two instruments, and that the earth is used for other conductor of the circuit. This is the customary manner of connecting two or more service buzzers in the field.

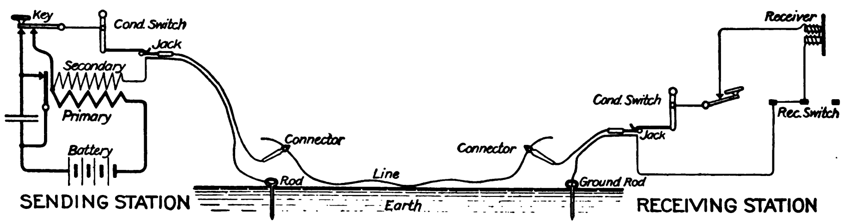


Fig. 3–33.—BUZZER, SERVICE, SENDING AND RECEIVING MORSE SIGNALS, CIRCUITS EMPLOYED.

Chapter 4.

CABLE AND CABLE SYSTEMS.

The cables provided by the Signal Corps are of two general classes, namely, submarine and subterranean. The two general classes may each be divided into two classes, depending upon the insulation used—whether rubber compound or paper. As the development of these cables has been along different lines, they will be described under separate headings.

SUBMARINE CABLES.

The first successful submarine cables employed gutta-percha as an insulating medium. This compound is subject to rapid deterioration when exposed to air, and for that reason such cable must be kept submerged at all times.

The general use of india rubber as an insulator in subterranean and aerial power cable work led American manufacturers to the development of this compound as an insulator for submarine cable, and many hundreds of miles of deep-sea, rubber-insulation submarine cable have been successfully laid and operated by the Signal Corps.

While it is frequently stated that rubber compounds used in deep-sea cable work are not materially affected by exposure to air for a considerable period, the Signal Corps has found it impracticable to store this class of cable without submerging, although rubber is undoubtedly vastly superior to gutta-percha in this respect.

The most serious problem in the design of rubber insulation cables for telephone work is due to the mechanical characteristics of the compound. Since the cable must be made up in twisted pairs in order to avoid trouble from induction, a tensile strain will tend to cause the conductors of the twisted pairs to press through the compound at points of crossing, lowering the insulation and eventually interrupting communication. This trouble is most marked in the larger types.

The corrosive action of sulphur used in the rubber compound, on the copper conductors is a trouble which is difficult to eradicate completely. Another difficulty which is common to both rubber and gutta-percha lies in the high capacity which results from the use of either of these forms of dielectric. On short lengths of cable this objection is not serious, but the fact that 25 miles of ordinary rubber-covered twisted pair is the limit of audible conversation must frequently be taken into consideration in designing cable.

As a result of many years experience in harbor cable maintenance the modified commercial types of cable indicated herein have been adopted.

While the use of rubber in this class of cables has been generally abandoned in favor of paper, the Signal Corps has retained this insulation for cables not exceeding six pairs in size. It is thought that in the smaller cables there is a slight advantage in simplicity of repair of rubber, and no marked economy is gained in the use of paper insulation. For cables from five pairs upward, there are many advantages in the adoption of the paper insulation.

RUBBER INSULATION SUBMARINE CABLES.

The conductors of these cables invariably consist of seven strands of annealed copper wire, 28.5 or 20.1 mils diameter, tinned to prevent as far as practicable the corrosive action of sulphur in the rubber. Each conductor is insulated as follows:

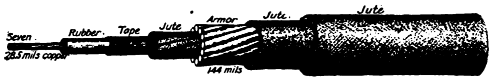
First. With a coating of fine Para rubber to a uniform thickness of one sixty-fourth of an inch.

Second. With a compound containing either 30 or 40 per cent of fine, unrecovered Para rubber to a uniform diameter of thirteen sixty-fourths of an inch, the compound being applied seamlessly.

Third. With a 30 per cent rubber compound, conforming to the requirements of Signal Corps specification to a diameter of nine thirty-seconds of an inch. The insulation is then covered with a layer of best cloth tape saturated with an approved rubber compound, and put on with a double lap.

It has been claimed that one layer of rubber compound instead of three is more satisfactory, consequently in future one layer only of either 40 per cent or 30 per cent compound will be applied in the manufacture of some of these cables.

In multiple conductor cables, two of the conductors are twisted together and all conductors are grouped together in such a manner that the finished core will be cylindrical. The core is then given two sufficient servings of best India jute roving, which has been previously steeped in a strong solution of cutch and dried. The jute serving is put on in reverse layers.



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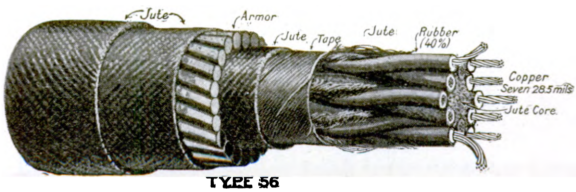

TYPE 56

Fig. 4–1.—CABLE, SUBMARINE, RUBBER INSULATION.

The core of the cable is then armored by having a number of steel wires wound spirally about it. The lay of the armor wire is left hand, the length of such lay being equal to 10 times the diameter of the cable, measured over the armor wires. Where a double armor is applied the outer has a right-hand lay. The diameter of the armor wires varies from 144 mils for 1-conductor cable to 229 mils for 12-conductor cable. They are invariably heavily galvanized and required to meet certain tests in this respect.

The completed cable is then served with two layers of India jute yarn, one being in reverse direction to that of the other, the cable being run through hot asphalt compound after placing each of the above layers of jute. To prevent sticking, the cômpleted cable is then run through powdered chalk (whiting) or other approved impalpably powdered rock.

The following table gives the principal characteristics of the latest approved types of rubber insulation cable used by the Signal Corps for submarine connections (see fig. 4–1).

For list of all types of rubber insulation cables that have been used for submarine connections, see chapter 8 of this Manual:

Type No.	Number of conductors.	Twisted pairs.	Conductor. Number of strands	Conductor. Diameter of each strand in mils.	Diameter over insulation.	Armor, diameter in mils.	Lay of armor not more than—	Per statute mile. Capacity not more than—	Per statute mile. Resistance of copper.	Length on reel unless otherwise specified.
					Inch.		*Inches.*	*M. F.*	*Ohms.*	*Feet.*
50	1	0	7	28.5	$\frac{18}{64}$	144	12	.5	9.7	10,560
51	2	1	7	28.5	$\frac{18}{64}$	144	12	.5	9.7	10,560
52	4	2	7	28.5	$\frac{18}{64}$	162	14	.5	9.7	10,560
53	6	3	7	28.5	$\frac{18}{64}$	204	16	.5	9.7	5,280
54	8	4	7	28.5	$\frac{18}{64}$	204	16	.5	9.7	5,280
55	10	5	7	28.5	$\frac{18}{64}$	229	18	.5	9.7	2,640
56	12	6	7	28.5	$\frac{18}{64}$	229	18	.5	9.7	2,640

NOTE.—Armor shall have a left-hand lay.

Rubber insulation cable may be furnished in double armor if installation is required in unusually rocky localities.

PAPER-INSULATION SUBMARINE CABLES.

The necessity for an insulation which would be free from the objections noted for rubber and the more numerous objections to gutta-percha led to the development of the paper-insulation cable. In case of a puncture of the sheath the paper core swells and dampness tends to work back but a very short distance. This cable is free from all of the objections cited for rubber and gutta-percha.

The conductors are insulated with two wraps of dry manila paper of such character and in such a manner as to meet specified capacity and insulation requirements. The insulating manila paper is plain in color for one conductor of each pair and colored for the other. The core of the cable is "laid up" in twisted pairs, each pair having four twists per foot. These pairs are "laid up" in successive layers, each successive layer being wound in reverse direction to the preceding layer, making a complete turn in from 18 to 36 inches. The whole core is served with a covering of heavy manila paper and encased in a lead sheath, the thickness of which varies with the size of the cable. Jute and armor are then applied in manner previously described in this chapter.

The following table gives the principal characteristics of the latest approved types of paper-insulation cable used by the Signal Corps for submarine connections. (See fig. 4–2.)

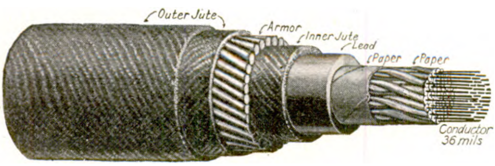

Fig. 4–2.—CABLE, SUBMARINE, PAPER INSULATION.

For list of all types of paper-insulation cables that have been used for submarine connections, see chapter 8 of this manual.

Paper insulation, lead covered and armored cable.

Type No.	Number of conductors.	Size of conductor, B. and S. gauge.	Size of armor, B. W. G. gauge.	Per statute mile.		
				Capacity.	Resistance of copper.	Weight.
				Microfarads.	*Ohms.*	*Pounds.*
320	10	19	6	0.10	45	20,400
321	20	19	4	.10	45	27,900
322	30	19	4	.10	45	29,880
324	40	19	4	.10	45	35,805
325	50	19	4	.10	45	39,115
326	60	19	4	.10	45	47,355
327	100	19	4	.10	45	57,750

NOTE.—All in twisted pair, double wrap, dry paper.

Reserve reels of paper-insulation cable are provided in all coast-defense commands having important submarine cable installations. Ordinarily all submarine cables are laid and repaired by the personnel of one of the Signal Corps cable ships. In the event of the cable ship not being available, the reserve cable can be laid to replace one that becomes unserviceable, by means of a tug and lighter, one or both of which can usually be obtained in the immediate vicinity.

The latter action is taken only when the exigencies of the service require communication, which has been interrupted, to be established before the cable ship can be sent to make the necessary repairs.

SUBTERRANEAN CABLES.

The manufacture of paper-insulation cable has been perfected to such a degree that the cost of this class of cable is far below that of the rubber-insulation type. Subterranean cable usually supplied for communication purposes is paper insulation, lead sheathed but not armored, it being understood that suitable conduits for the installation will be provided. Where it is impracticable to furnish a conduit, lead-covered and armored cable is furnished (regardless of insulation), and the cable is laid in a trench approximately 2 feet deep and then covered with earth. The manufacture of rubber-insulation subterranean cable and paper-insulation subterranean cable are so similar to cables with same insulation for submarine work previously described in this chapter that detailed description would be superfluous. Suffice it to say that invariably cable for submarine work is supplied with an armor regardless of nature of insulation and in addition a lead sheath if the insulation be paper, while cable for subterranean use is armored only when it is intended that it shall be trenched or placed in an exposed location.

Double lead-covered cable may be supplied for installation in marshes or similar locations where mechanical damage is unlikely.

The following tables indicate the latest approved types of subterranean cables used for lines of communication.

For complete lists of cables that have been used for subterranean work, see chapter 8 of this manual.

Rubber insulation subterranean cable.

[See fig. 4-3.]

Type No.	Number of conductors.	Number and size of strands B. and S. gauge.	Diameter over insulation (rubber).	Armor. B. W. G. gauge.	Weight per mile.	Length on reel.
			Inch.		*Pounds.*	*Mile.*
213	2	7-24	5/32	....	3,000	½
214	6	7-24	5/32	....	9,200	½
						Feet.
215	12	7-24	5/32	....	11,100	1,000
216	24	7-24	5/32	....	14,785	1,000
217	12	7-24	5/32	14	18,800	1,000
218	24	7-24	5/32	9	26,900	1,000
251	2	1-18	4/32	[1]	....	1,000

[1] Steel tape.

NOTE.—All in twisted pair, with ⅛-inch lead sheath, except the type 251, which has a 1/32-inch lead sheath.

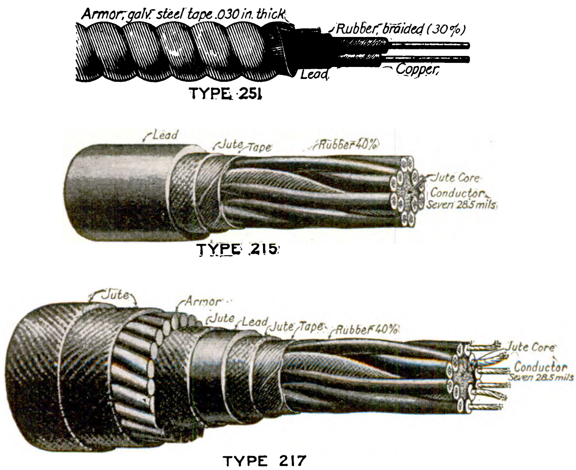

Fig. 4-3.—CABLE, SUBTERRANEAN, RUBBER INSULATION.

Paper insulation, lead-covered cable.

[See fig. 4-4.]

Type No.	Designation.	Conductor, diameter of each strand in mils.	Thickness of lead sheath.	Approximate outside diameter.	Weight per statute mile.	Weight per 1,000 feet of cable and reel.
				Inches.	*Pounds.*	*Pounds.*
401	10-pair..............................	36	3/32	0.722	5,370	1,186
402	15-pair..............................	36	3/32	.797	6,193	1,368
403	20-pair..............................	36	3/32	.872	7,054	1,558
404	25-pair..............................	36	3/32	.922	7,693	1,700
405	30-pair..............................	36	3/32	.982	8,416	1,860
406	40-pair..............................	36	7/64	1.113	11,083	2,448
407	50-pair..............................	36	7/64	1.208	12,445	2,750
408	75-pair..............................	36	7/64	1.443	15,829	3,497
409	100-pair.............................	36	7/64	1.638	18,860	3,967

NOTE.—Al in twisted pair, double wrap, dry paper.

Paper insulation, double lead-covered cable.

[See fig. 4-4.]

Type No.	Number of conductors.	Size, B. and S. gauge.	Per statute mile.		
			Capacity.	Resistance of copper.	Weight.
			Microfarads.	*Ohms.*	*Pounds.*
312	10	19	0.10	45	15,100
313	20	19	.10	45	18,400
314	30	19	.10	45	21,100
315	50	19	.10	45	23,000
316	60	19	.10	45	24,400
317	100	19	.10	45	26,400

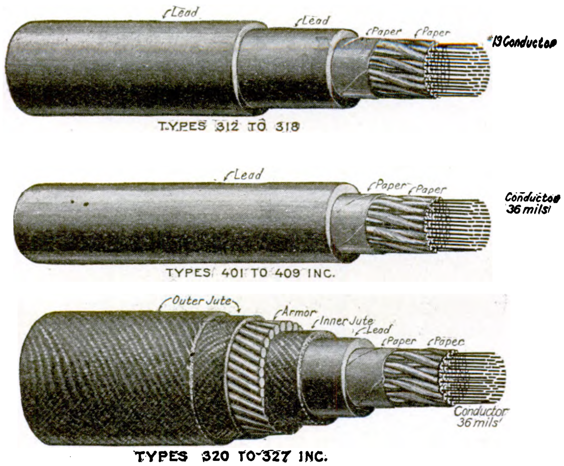

Fig. 4-4.—CABLE, SUBTERRANEAN, PAPER INSULATION.

It will be noted that paper insulation cable, lead covered and armored, may be used either for submarine work or subterranean work where it is intended that the cable be trenched.

POWER CABLE.

Cables used for transmitting power such as are necessary in underground lighting and power systems, the charging and discharging of storage batteries or any use where the strength of current employed is large as compared with that of a telephone or telegraph circuit, are termed power cables.

Power cables employing paper insulation are quite extensively used in the commercial world, but it is believed that all things considered the rubber insulation cable is more satisfactory for this purpose, and for that reason all power cables furnished by the Signal Corps are of the latter class.

The rule which prescribes armor for subterranean communication cables laid in trench applies also for the installation of power cables.

The following table indicates power cables usually carried in stock by the Signal Corps. For complete list of power cable that can be supplied, see chapter 8. It is important to note that these power cables may be furnished in a number of sizes and that each size may be single or duplex, also that any of the cables can be supplied with either an outer braid, lead sheath, or lead sheath and armor.

Rubber insulation power cable.

[See Fig. 4-5.]

Type numbers.			Area circular mils.	Number of strands per conductor.	Diameter of single wires.	Resistance of conductor per 1,000 feet, 68° F.	Thickness of wall of rubber insulation.	Length on reel.		Thickness of lead.	Diameter of armor wires.
Single L. C.	Duplex L. C.	Duplex L. C. and armored.						Single braided and single L. C.	Duplex L. C. and duplex armored.		
					Mils.		*Inch.*	*Feet.*	*Feet.*	*Inch.*	*Mils.*
622	642	662	6,530	1	80.81	1.586	$\frac{3}{64}$	2,000	1,000	$\frac{3}{32}$	114
623	643	663	10,380	1	102.0	.9972	$\frac{3}{32}$	1,500	1,000	$\frac{1}{8}$	114
624	644	664	16,510	7	48.6	.6271	$\frac{3}{32}$	1,500	1,000	$\frac{1}{8}$	114
625	645	665	26,250	7	61.2	.3944	$\frac{3}{32}$	1,500	1,000	$\frac{1}{8}$	144
626	646	666	33,100	7	68.8	.3128	$\frac{3}{32}$	1,500	1,000	$\frac{1}{8}$	144
627	647	667	41,740	7	77.2	.2480	$\frac{3}{32}$	1,500	1,000	$\frac{1}{8}$	162

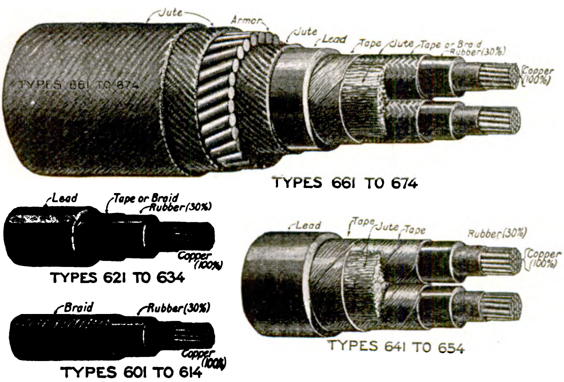

Fig. 4-5.—CABLE, POWER.

Cable Reels.

In order to maintain a complete history of the various cables, each reel of Signal Corps cable bears a brass tag marked with the letters "S. C." and a serial number, this tag being attached to the reel when the cable thereon is accepted by the Signal Corps inspector. The tag is for the purpose of identifying the reel and also the cable and will be removed only when the reel is returned directly to the manufacturer, which shipment should not be made except under advice from the Chief Signal Officer of the Army.

The Chief Signal Officer of the Army will assign reel numbers at the time order for cable is placed. The Department Signal Officer, Eastern Department, will have charge of and issue reel tags. When cable is manufactured in another department and inspection is under the direction of the Department Signal Officer of that department, application will be made to the Department Signal Officer, Eastern Department, who will furnish the necessary tags for attachment to reels. Upon the placing of cable order, the Department Signal Officer, Eastern Department, and the department signal officer under whose direction inspection is to be made will be furnished with a copy. The latter will cause the inspector to see that the reel number and marking for the shipment as shown in the order is followed, that the manufacturer's name and reel number appear on the reel in some permanent form (manufacturer's name and number will be omitted when the reel becomes the property of the Signal Corps by terms of the order), and will advise the Chief Signal Officer of the Army of the manufacturer's reel numbers corresponding with Signal Corps reel numbers. If cable is transferred from one reel to another, report will be made at once to the Chief Signal Officer of the Army through the Department Signal Officer, showing the amount and type of cable, the reel from which removed, and the reel on which wound. Cable should not be transferred to a reel known not to be the property of the Signal Corps if it is possible to avoid it. It is not desired that full lengths of cable held in stock be transferred for the purpose of freeing manufacturer's reels, but other conditions being equal, cable on reels the property of manufacturers should be used first.

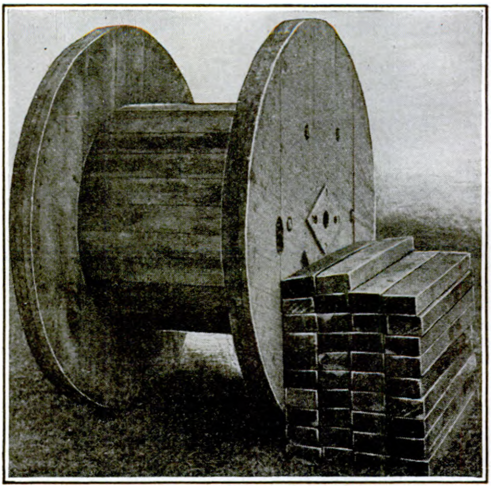

Fig. 4-6.—REEL, CABLE, WITH LAGGING.

In the installation of cable systems it is customary to collect a quantity of empty reels before returning them to one of the general supply depots if property of the Signal Corps, or the manufacturer if property of the contractor. Construction parties should invariably return lagging to reel as soon as practicable inasmuch as the lagging is considered a part of the reel. In former years the lagging of cable reels was given away or used as kindling for fire, but the material advance in the cost of lumber has made such action a waste that is prohibited. Manufacturers require that the unbroken lagging be returned with reels.

Installation of Cables.

Submarine cables are usually laid by the personnel of one of the cable ships. The cable ships for laying and repairing harbor fire-control cables are each equipped with an enormous reel permanently installed in a vertical position on forward main deck. The revolving of this reel in either direction is accomplished by means of electric motors under control of an operator who is stationed near reel. The cable to be laid is wound on reel described above, thereby releasing reels upon which cable was shipped. As the ship's reel will hold many miles of cable, it is probable that the amount to be laid may comprise that contained on several shipping reels. Before proceeding with the actual laying it will be necessary, of course, to splice the cable from the several shipping reels. The shore ends of the cable are landed by employing ship's launch and small boats. When one end has been landed and securely fastened the ship proceeds over the route selected, the cable paying out over a large sheave at a speed regulated by the reel operator. Continuous tests during the laying of the cable are made with delicate testing apparatus in order that a fault may be detected as soon as possible. When the landing of cable is completed, the ends are securely anchored by means of chains. It is more desirable that a submarine cable separate than to have the ends pulled out to sea. After a cable is laid, a report, showing its type, length, number of splices, insulation resistance, ohmic resistance, electrostatic capacity, and other data is submitted by the commanding officer of cable ship to the Chief Signal Officer of the Army and copies to others who are authorized to receive such reports.

In harbors, to avoid as much as possible, interruptions, due to rupture of cables by ship anchors, not only have routes been selected which will avoid crossing "much used" anchorages, but a list of forbidden anchorages covering paths of all submarine cables installed by the Signal Corps has been prepared and furnished the Hydrographic Office of the Navy Department, with request that it be embodied in "Notice to Mariners" issued by that office. It is believed that this action will obviate to a great degree interruptions which have been occasioned by vessels anchoring in the vicinity of cables.

Signs reading "Cable crossing—don't anchor" have been installed at suitable points near cable landings, and while in some instances such action has been effective, in a great many instances the signs have apparently been ignored.

Complete list of cable gear and supplies may be found in chapter 8 of this manual.

Aerial Cable.

Sometimes cables used in post telephone systems are installed aerially, existing pole lines being employed as much as possible. In the installation of aerial cable a messenger consisting of stranded galvanized-steel cable is stretched tightly and fastened securely at each pole, care having been previously taken to guy the poles substantially where necessary. The cable is then drawn along messenger, being suspended from it by hangers, one type of which is made fast to cable, another type being clamped to messenger.

Underground Cable.

It is desirable to place cables under ground wherever practicable. This avoids the pole lines and the necessity for running pole lines about the post in conspicuous locations, secures the cable from many sources of injury common to aerial lines, and makes the system reliable in operation and easy to maintain. Underground construction will, in general, be more expensive than aerial, and this consideration will usually determine the form of construction to be followed. The first step is to decide on the general layout of the system. The procedure should, in general, be the same as outlined for the aerial plant. In selecting the routes, attention should be given to the contour of the post; location of material obstacles to cable runs; buildings, existing and projected, and probable extensions of the system in the future. The runs between manholes should be without curves or bends. A diagram of pair distribution similar to figure 4–7 should be made, after which the lengths of the various sizes of cable can be determined.

Two general methods of placing cable under ground may be followed—trenching and conduit. The first costs less to install and does not require skilled labor, but has the disadvantage that the cable is not readily accessible for repair and once installed can not easily be recovered. Trenched cable is also more liable to mechanical injury after laying. It may be stated as general that trenching will be confined to lateral runs of type 251 cable. All paper-insulation cable, as far as practicable, will be placed in conduit.

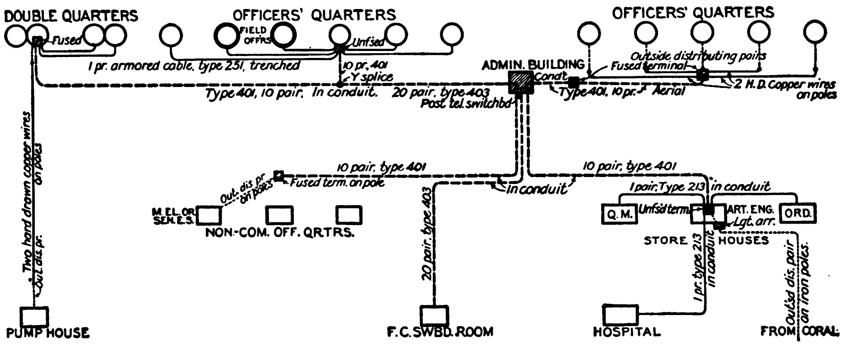

Fig. 4–7.—CABLE SYSTEM, DIAGRAMMATIC.

Trenching Cable.

The route being staked out, the trench should be excavated of sufficient width and not less than 18 inches in depth if practicable. Care should be taken that the bottom of the trench and the first earth used for filling in are entirely free from stones, sticks, or other material which will injure the cable sheath under pressure. The cable may be pulled into the completed trench from the reel, held on cable jacks. In pulling into trench, avoid drawing cable over sharp projections which would score the sheath. The same precautions should be employed in sealing ends, splicing, and pot-heading as for aerial cable. After the cable is laid and spliced the trench may be filled. The route of trench with splices located should be recorded on scale map.

Conduit.

In all conduit construction the following general outline will apply:

The top of the conduit line should never be less than 18 inches below the surface. In many places this depth will be exceeded in order to maintain the grade of the duct line. The distance between manholes should be as great as local conditions and the length of the cable that can be pulled into a duct will permit. Where fiber or pump log conduit are used this distance should not exceed 400 feet; for clay conduit 350 is considered the maximum. As cable is usually furnished in lengths of 1,000 feet, the spacing should be such as to cut this length without waste or accumulation of short pieces.

In general, it is desirable to run conduit or trench in rear of buildings and quarters to avoid cutting up turf or lawns unnecessarily. The location of the main line should be such as to afford the most economical and convenient distribution to stations. All excavations, especially on roadways, should be guarded outside of working hours by suitable barricade and lanterns to prevent injury to traffic. Avoid opening long stretches of trench in which the cable or conduit can not be laid without delay. In many cases a plow may be used to good advantage to remove the top layer of earth. Conduit will not be laid in concrete unless four or more ducts are used. Conduit should be laid in straight line, and at same grade between manholes if practicable. All changes in direction should be made at a manhole or handhole. The bottom of the trench should be smooth and firmly tamped before laying conduit. All work in connection with conduit construction should be accomplished under the supervision of a thoroughly competent foreman.

The types of conduit used are bituminized fiber, pump log, and vitrified clay. For most of the Signal Corps work the fiber conduit will be used on account of ease of installation and small first cost of material.

The vitrified-clay conduit is suitable for conditions requiring unusual strength and rigidity. The plans shown herein are for fiber conduit in all cases. Where this type is not available use may be made of either of the other types.

The standard fiber conduit is made in 5-foot lengths, 3-inch inside diameter and three-eighths inch wall, weighing 2 pounds per foot. The lengths of conduit are made with male and female slip joints as shown in figure 4–8. When

Fig. 4–8.—CABLE SYSTEM, CONDUIT ENDS.

laying the conduit the end of each section should be dipped into a waterproofing liquid before jointing. Care should be taken to close the joint completely and to avoid placing stones or other material next the conduit in filling. The work of laying may be begun at a manhole or at any part of the trench. Where the conduit work is discontinued temporarily for any cause the exposed duct ends should be plugged and covered with a tarpaulin until work is resumed. Where short lengths are required the standard pieces may be cut with a handsaw, using water to prevent sticking of the saw. Care should be used in handling the conduit to avoid breaking the ends. The fiber conduit is made up in the usual elbows, tees, and bends.

MANHOLES.

To provide for access to conduit for pulling, splicing, inspection, and repair of cables, manholes are placed as needed. The usual form is shown in figure 4–9. The dimensions of this figure may be varied to suit special conditions. A large number of formulae are in use for mixing concrete. The proportions for stone, sand, and cement vary with the size and character of the stone, the quality of the cement, and the purpose for which the concrete is to be used. A good general formula is 1 part cement, 3 parts sand, and 6 parts stone. For gravel, 1–2½–5 will be better. In making estimates it should be borne in mind that the volumes of cement, gravel, sand, and stone taken separately will be

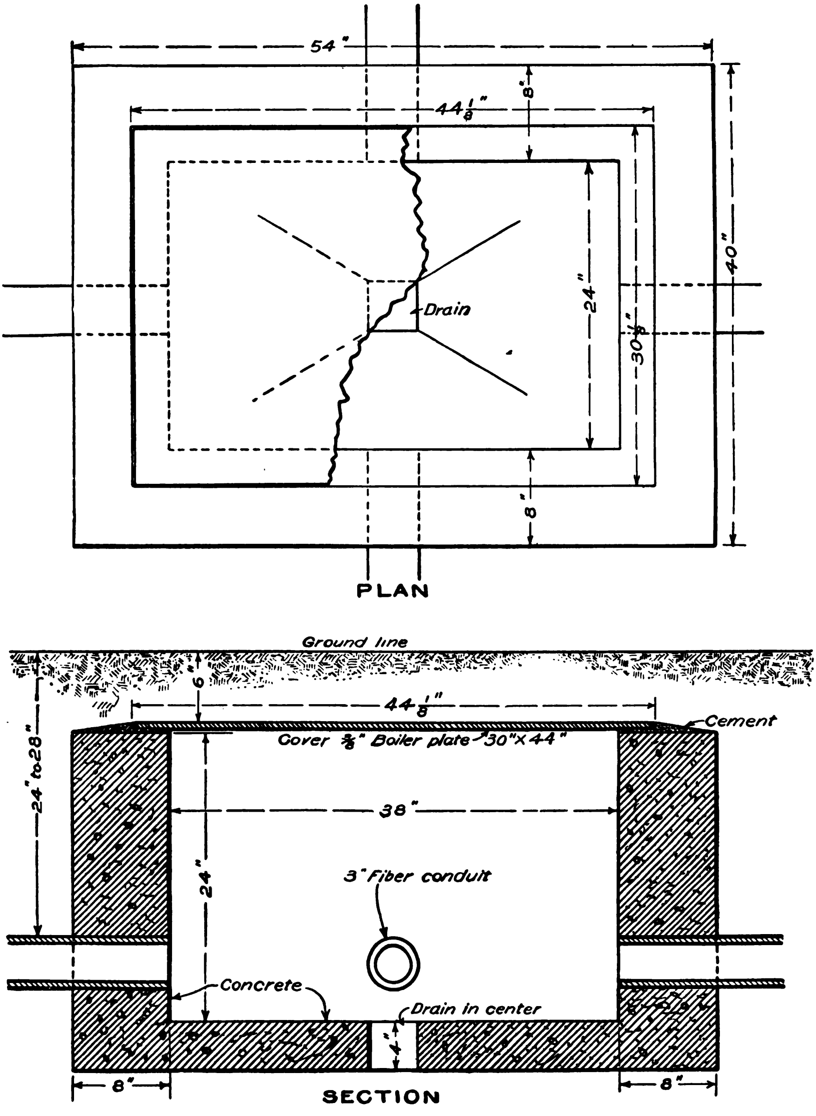

Fig. 4–9.—CABLE SYSTEM, MANHOLE.

greater than the volume of the finished concrete, and allowance must be made accordingly. Thus, for 1 cubic yard of concrete by the formula 1–3–6, there will be necessary 1.1 barrels of cement, 0.46 cubic yard sand, and 0.93 cubic yard stone. One barrel of cement contains four bags. The formula is for parts

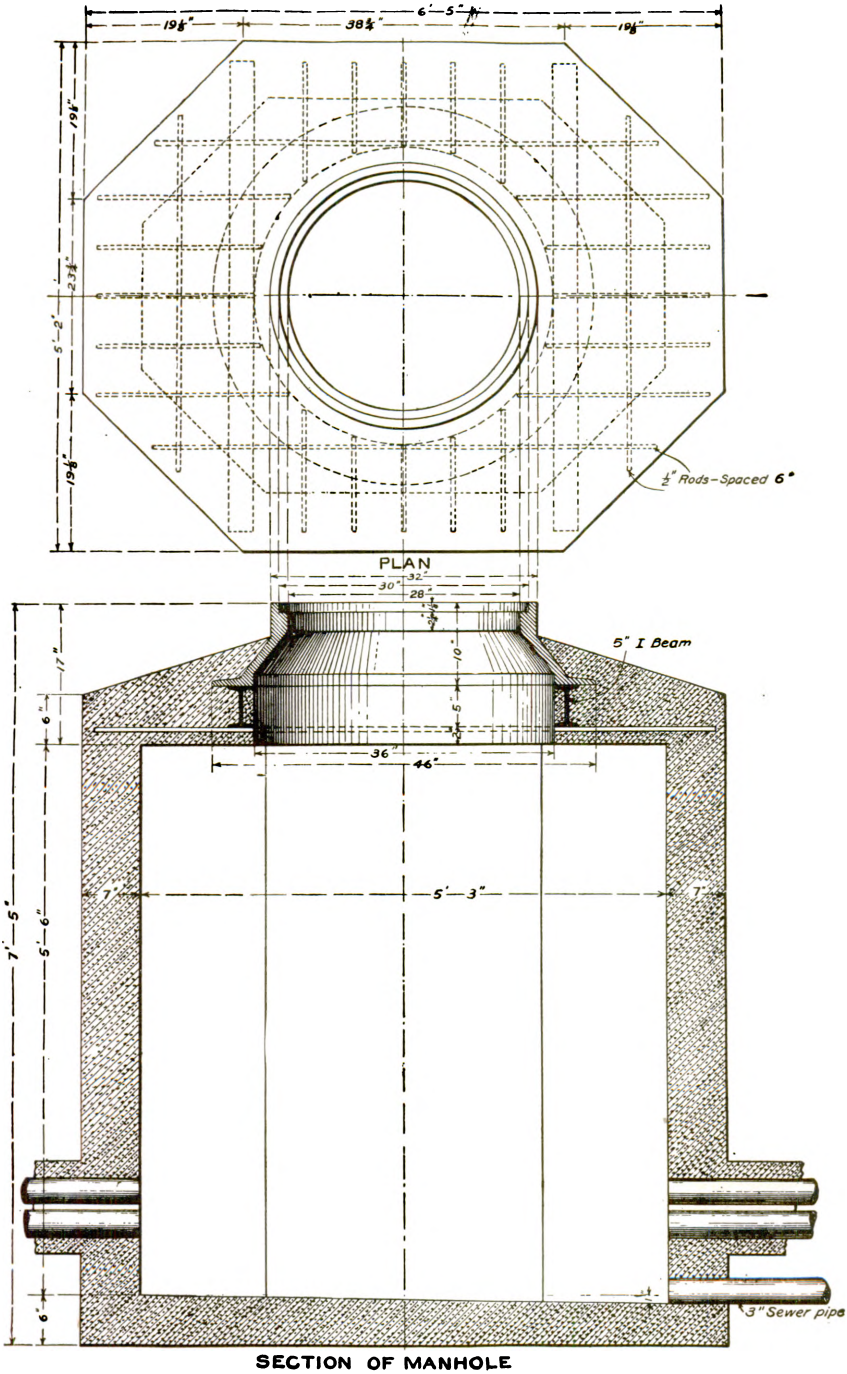

Fig. 4–10.—CABLE SYSTEM, MANHOLE WITH CONCRETE TOP.

by volume. The cement should be only the best grade Portland, the sand free from loam or similar foreign matter, the stone hard and sharp, screened, and not larger than will pass through a 1½-inch ring. The cement should be stored only in a perfectly dry place. The materials should be thoroughly mixed before adding water. Only such quantities should be mixed as can be placed without a delay of more than 45 minutes. Water should be added very gradually and thoroughly mixed with the materials as applied. The materials should be accurately measured and not estimated. Mixing should be done on a board, never on the ground. The excavation for the manhole being completed, the bottom shall first be laid, extendding under the manhole walls. The concrete shall be tamped in place and the surfaces smoothed off.

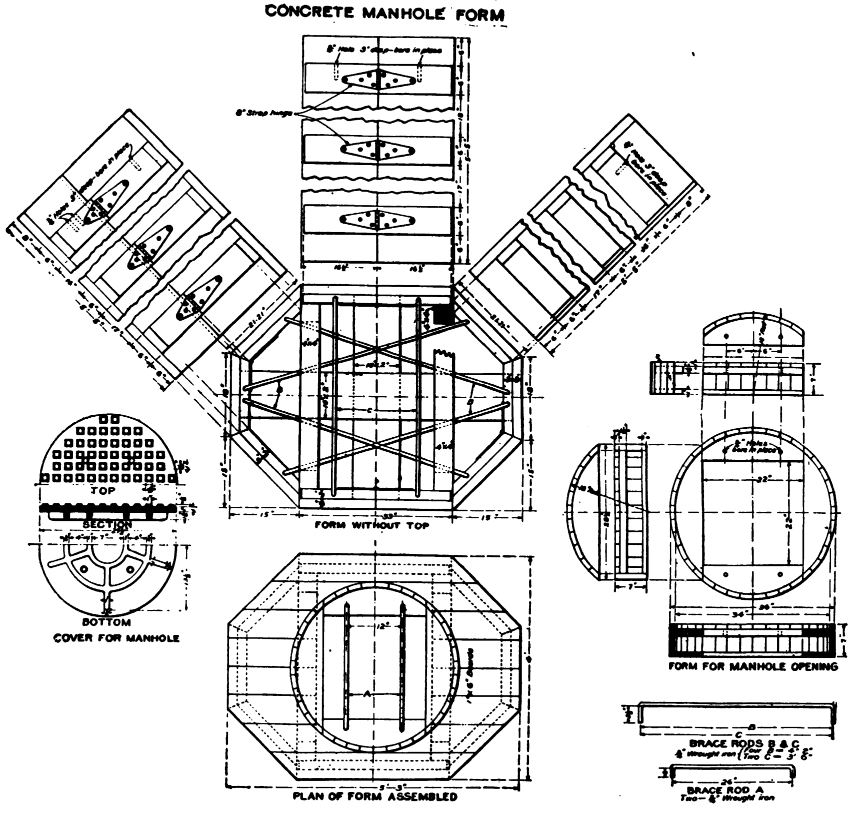

Fig. 4–11.—CABLE SYSTEM, MANHOLE, REMOVABLE FORMS.

The form for the walls should be made of good dressed lumber, substantially put together to withstand the pressure of the concrete. The forms should be so built as to be easily removed for use elsewhere. After forms are set and properly braced the concrete should be placed to form a wall of the required thickness. In some locations no outside form will be required, the earth wall serving this end. The concrete should be deposited in layers not more than 6 inches thick and rammed in place until the surface becomes slightly fluid. The manhole should be completed at one operation. A surface for the cover is made of cement and the cover placed before the cement has set. In figure 4–9 the cover is shown 6 inches below the surface, to allow for resodding. Where this is not required the depth of the duct line below the surface may be reduced to place cover flush with ground line. In many cases where it is necessary to provide access to duct for distribution, inspection, etc., a much smaller manhole, usually termed "handhole," will be sufficient. This should follow the general outline of figure 4–9, with an inside diameter of 12 by 15 and 12 inches deep, walls not over 6 inches thick. In many cases where the handhole is used to end a lateral to a building the foundation may form one side of the handhole. The method of construction is the same as for manholes. It is desirable to have only one size for all manholes and for all handholes, so that one set of forms will do for each type. Where concrete can not be used, recourse may be had to brick or, in emergency, creosoted plank not less than 2 inches thick. In some instances it is advisable to furnish a cover equipped with a throat in order that entrance to manhole will be flush with earth's surface, and in other instances a more expensive construction such as is shown in figure 4–10 may be desired. The latter has a cast-iron cover of somewhat different design adapted to withstand heavy traffic. The dimensions of manhole given in this figure are not to be taken as standard. The type to be adopted depends on the number of ducts, local contours, location, etc. In figure 4–11 is shown a set of removable forms for constructing concrete manholes of this character. Where a number are to be constructed of one size it will be found desirable to use this or a similar set of forms. These should be made by local labor and of serviceable lumber.

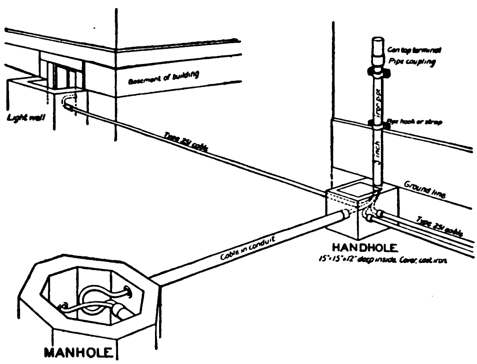

Fig. 4–12.—CABLE SYSTEM, DISTRIBUTION.

The method to be used in branching from a main-line conduit to a building or group of buildings requires careful thought. Where the lateral is of sufficient length and the number of pairs requires a paper-insulation cable, a branch line of duct with a handhole, as shown in figure 4–12, should be used. The handhole is located at the wall of the central structure of the group, and the cable ends in a can terminal, as shown. From the can terminal single-pair cables are brought down to the handholes and are then run to each of the buildings, being trenched only after leaving the handhole. The height of the can terminal above the ground is not fixed, but usually should be about 5 feet. In some cases the terminals may be placed in basements, under porches, inside storehouses, etc., where the installation can be simplified. Connection from underground to aerial cable may be made as shown in figure 4–13.

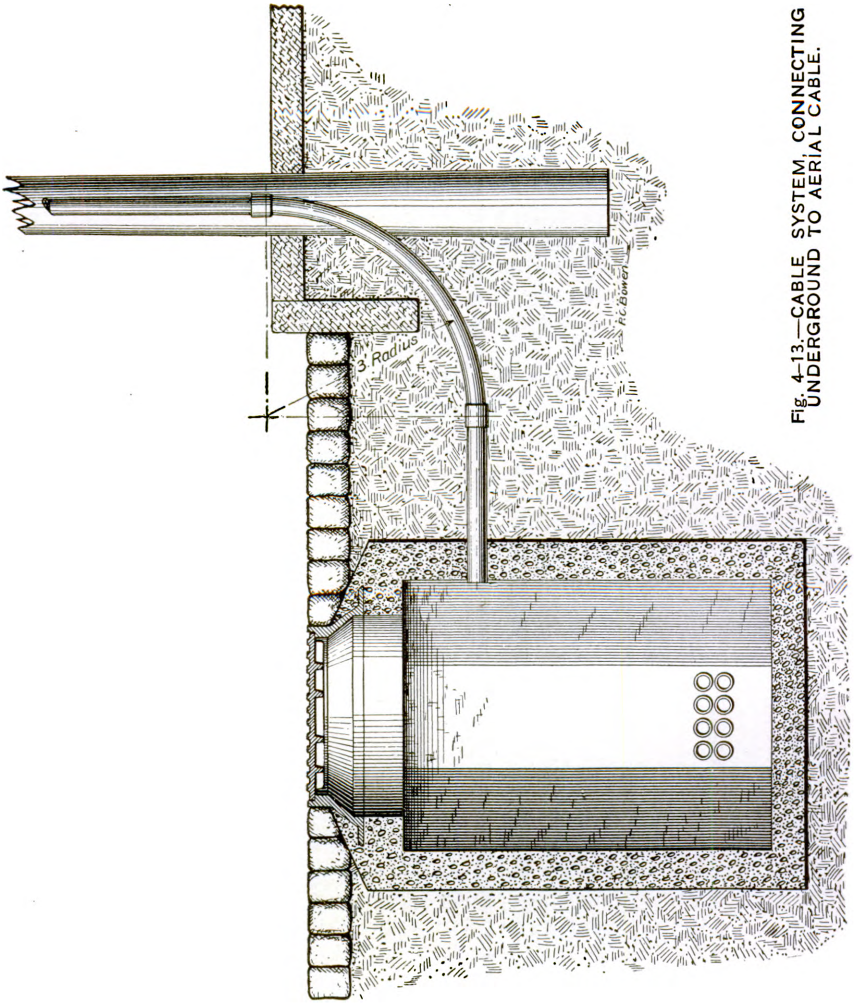

Fig. 4-13.—CABLE SYSTEM, CONNECTING UNDERGROUND TO AERIAL CABLE.

PULLING CABLE IN CONDUITS.

Under no circumstances should a cable splice be pulled in conduit.

The conduit system being completed, preparation for pulling in cable is made by threading a rope through the ducts. This may be accomplished by first pushing through duct rods of sections 3 or 4 feet in length, with coupling devices on each end, or a steel wire, known as a "fish wire" or "snake." (Use may be made of wooden strips, approximately ½ by 1 inch, cross section, notched at the ends and spliced together with iron wire or by means of taping, the two ends to be taped separately and again wrapping the ends with tape, after the two have been placed together.)

The pulling-in rope is now attached to one end of the length of wire or rods in the duct and pulled in. The cable reel is placed near manhole on jacks, as shown in figure 4–14.

One or more men tend the reel and see that the cable feeds off freely. A man in the manhole directs the cable into the duct and prevents injury to sheath from pulling across sharp corners. The pulling-in rope may be attached to cable by a manufactured device shown at bottom of figure 4–15, or by an improvised one shown at top of same figure, which is made as follows:

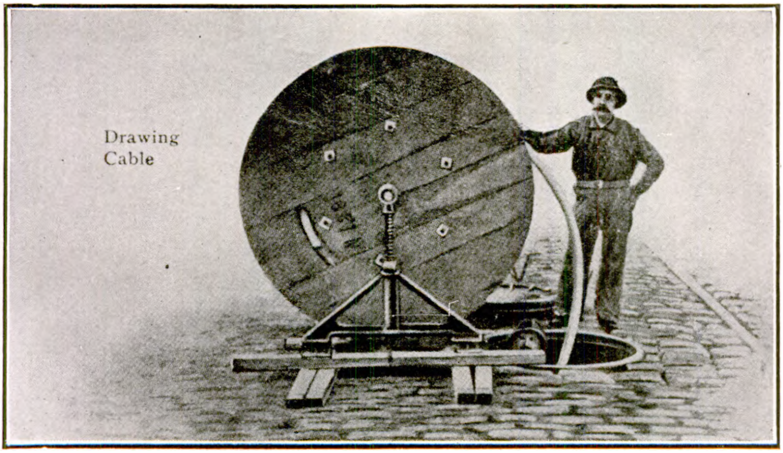

Fig. 4–14.—CABLE PULLING, POSITION OF REEL.

Place a block of wood about 3 inches wide against the end of the cable; cut 6-foot lengths of number 10 or 12 B. W. G. steel wire; take two, three, or four of these wires, depending on the severity of the pull, and bunch them together, bend them in the middle on the block of wood, then wrap the two halves spirally around the cable sheath in opposite directions, twisting the ends securely together. When the pull of the rope comes on these wires, they bind harder on each other, on the lead, the insulation, and the conductors, as the pull grows harder. The seal on the lead of the cable is not broken, and no water can come in contact with the insulation.

In pulling in paper-insulation cable of large size where the strain is unusually great, it is advisable to make pulling rope fast to all conductors, as well as sheath, in manner just described. This method is objectionable, however, especially if there be mud or water in ducts, and is only resorted to by the Signal Corps when there is danger of stretching lead sheath of cable to a dangerous degree.

Manila rope is used for drawing cable, though steel rope may be used. The ends of the rope should be fitted with an eye around a steel thimble fastened to a short length of chain with a swivel. The swivel may have a pair of sister hooks, all as shown in figure 4–15.

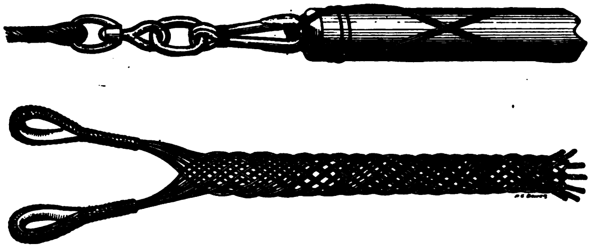

Fig. 4–15.—CABLE GRIPS, IMPROVISED AND MANUFACTURED.

If the cable is small and run short, it may be pulled in by hand. For heavy cables, winches, windlass, or horsepower may be used. The rope should be led from the duct to surface over pulleys when the depth of the manhole makes a direct pull inadvisable. Two pulleys on shafts which can be inserted in any of a number of holes in two channels are used for this purpose, the lower pulley being placed opposite the duct and the upper at a height sufficient to carry the rope out of the manhole. Enough slack cable should be left in each manhole for splicing and placing the cables along the sides, leaving the center clear. After drawing in, examine all ends carefully to see that the seal is intact. Two or even three cables of the sizes commonly used in Signal Corps work may be pulled into one duct if drawn together. Pulling in a second cable with one already installed should be avoided if practicable.

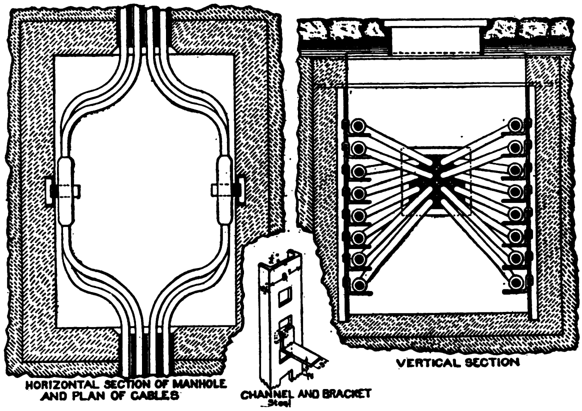

Fig. 4–16.—CABLE RACKING IN MANHOLES.

When distance between manholes is not over 200 feet cable may be pulled through one manhole and on to next, provided the pull is in a continuous straight line. The advisability of doing this is strictly a matter of judgment on the part of person in charge of cable pulling and should be regulated by the amount of extra strain on cable caused by such action. When a cable is pulled through one manhole and on to the next, slack should be pulled back in the intermediate manhole in order that cable may be racked on sides, thereby keeping center of all manholes clear.

A zinc tag on which is stamped the designation number is attached to each cable in each manhole by means of galvanized-iron wire. In manholes where cable is to be spliced, the tag described above should be placed on each of the two ends to be spliced together in order that splicer will not make a mistake.

As soon as cable has been pulled in ducts the Signal Corps representative supervising cable pulling must complete a preliminary record which has been prepared on the ground prior to initiation of cable pulling and upon which has been recorded designation number, type, and pair size of each cable of the system and the number of the duct to be used in each stretch for each cable. The following is also recorded: Pulled length of cable, reel number from which cable was taken, and date pulled. The name of splicer and the date of making each splice is entered on this record after splicing is initiated.

The arrangement of cables in manholes should be carefully planned to avoid sharp bends, have all cables accessible for inspection and repair, and keep the center free for future operations. The cables should be supported on the side walls by hangers or supports of a type similar to those shown in figure 4–16. This figure shows the ideal arrangement for a large number of cables. Where only one or two cables are in place they may be supported by means of pipe straps attached to wall with screws and expansion anchors.

Cable Splicing.

The splicing of cable is an operation which should be undertaken only by an experienced man. In the installation of cable systems there should be employed for splicing the subterranean cables one or more cable splicers who have previously shown that their work is satisfactory. If it becomes necessary to employ one who is not known, his work should be closely scrutinized by person in charge of the installation until satisfied that he is competent.

The importance of the above will be realized when the fact is considered that cables of any great length must necessarily contain a number of splices, and that a splice poorly made may not only make "test after laying" (which will be described later) indicate that the cable is faulty, but may render the circuits contained in the cable inoperative if repairs are not made.

When laying submarine cable the splicing is invariably accomplished by the personnel of the cable ship. These men have had a wide experience in this branch of work and are experts in their line.

The Signal Corps issues a chest containing all necessary tools for the work of splicing cables, the contents of which are enumerated in chapter 8 of this manual.

Where an emergency splice must be made, the following directions should be followed:

SPLICING RUBBER INSULATION SUBMARINE CABLE.

Materials required:

Pure rubber.
Rubber cement.
Serving mallet (can be improvised).
Small soldering kit.
Spun yarn for seizing.
Sandpaper.
Alcohol.
Splicing compound
Tape, okonite.
Tape, friction.
Tape, P. & B.
Small coil 51 mils galvanized iron wire (seizing).
Vulcanizer (if vulcanized splice).
60 per cent compound (if vulcanized splice).

(*a*) Cut the ends of the cable to be spliced squarely off and have one overlap the other about 15 feet.

(*b*) The armor wires are then carefully untwisted from one of the ends for about 15 feet in groups of about five. These should be carefully handled so they will go back into place easily (fig. 4–17).

(*c*) Before unlaying armor wires some small galvanized wire, called "seizing," is wound tightly around the cable here to prevent the untwisting from going any farther back.

(*d*) The jute padding is then untwisted and the core is cut off to within a foot of the small wire seizing, and the jute, about 2 feet from it. Meantime a seizing of small wire is wound about 6 inches from the other end of the cable.

(*e*) The armor wires are nicked with a file and broken off close to the latter seizing.

(*f*) The armor wires are then smoothed with a file.

(*g*) The jute is stripped off the short end.

(*h*) The tape is taken off for 6 inches at each end.

(*i*) The rubber insulation is cut in cone shape with a sharp knife (fig. 4–17), leaving about 3 inches of conductor exposed at each end. The copper-conductor strands are spread out for 1½ inches, the central wire being cut out of each for that length.

(*j*) The wires are well cleaned with fine sandpaper and the ends are interlaced and neatly and closely wound about the twisted parts of each other.

(*k*) The joints should be soldered at the ends of the copper strands only, using a very little resin as a flux. Care must be taken to prevent the resin from touching the clean rubber surfaces. Acid soldering flux of any kind must positively not be used.

A well-vulcanized insulation for the joint is always desirable, but proper vulcanizing requires almost laboratory conditions and considerable extra time, and where a cable is being spliced on shipboard with ship pitching in rough water, time may be a vital factor. In view of this, there has been developed by the Signal Corps a method of insulating submarine cable joints without vulcanizing, which has proved highly satisfactory. The joint produced by this method is termed a "raw joint" and has been used with marked success for over five years by personnel of the U. S. Army transport *Burnside*. The cable ends are prepared and the two ends of conductor joined as described above. Continued description is as follows:

In preparing the conductor of each cable before joining same, allow at least 2 inches of the core to be exposed from where it comes out of the jute to the end of the cone or "pencil point" of the rubber insulation. One inch of this will be taken up in forming the cone shape, the other inch of exposed core retaining its original cylindrical shape.

Before proceeding further it is well to note that upon the proper care in preparing these 2 inches of core at either side of the joint, may depend the success or failure of the insulating qualities of the finished splice.

In shaping the cone, which is done with a sharp knife, the core is grasped in the left hand and pulled taut; at the place where the cone is to terminate nick the surface of the rubber for a marker, placing the forefinger of the left hand for support under that part of the core where the cone is about to be shaped, commence making the cut, drawing the blade of the knife toward the hand holding the core, giving the blade a sawing movement, which will assist greatly in the cutting, particularly if the rubber is soft and fresh. Do not try to make speed or save labor by forming the cone in

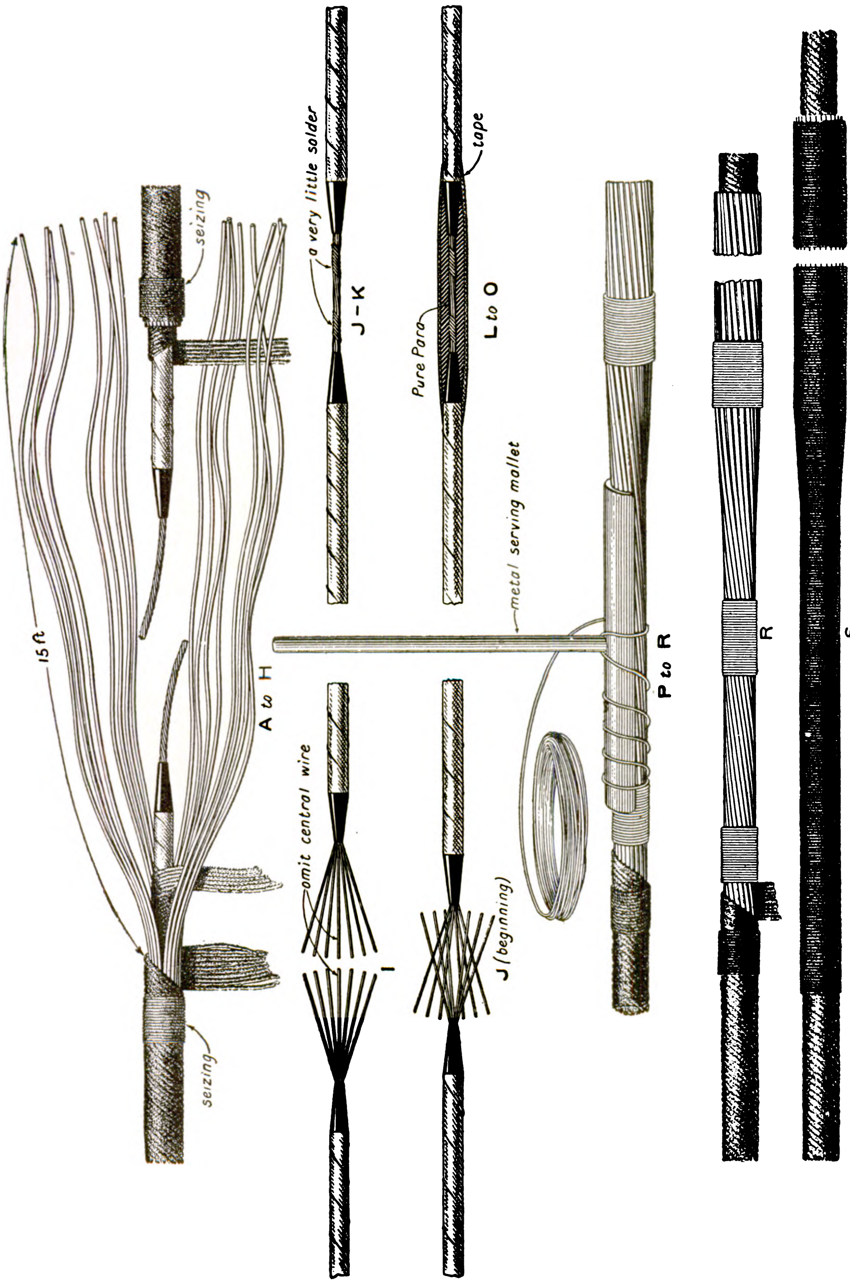

Fig. 4-17.—CABLE, SUBMARINE, SPLICING.

only four or five cuts. After the cone has been shaped with the knife as well as possible, care having been taken at all times not to nick the copper conductor, a piece of rough sandpaper, about No. 2, is then used to round up the cone, removing all flat places and ridges, this sandpapering also continuing vigorously and thoroughly over that portion of the core which retains its cylindrical shape. Any flat places or ridges not removed from this part of the core will have a tendency to form grooves along the core under insulating material which will cover it, allowing moisture to work its way in to the conductor.

If the cylindrical part of the core is not thoroughly cleaned and roughened by the sandpapering, that adhesion which is necessary between core and insulating material wrapped on will not take place.

The conductors having been joined and the ends soldered, the rubber core and conductor over which the insulation is to be wrapped should be washed with alcohol on a piece of clean cloth or waste to remove any oil, dirt, or moisture that may have been deposited on them due to handling.

Allow adhering alcohol to evaporate. If necessary, then scrape the rubber with the edge of knife blade, to remove any lint or threads that may have been left on the rubber after washing with alcohol.

The joint is now ready for the insulating materials to be wrapped on.

The part of joint most susceptible to leakage is where the insulating material and rubber core join. A good grade of rubber cement, such as is used for patching the inner tubes of automobile tires, should then be put on the rubber core and rubbed into the pores of the rubber, which has been roughened and scraped for this purpose. When this first coating, which has been put on rather thin, has dried—which it will do almost immediately—a second coating should be applied, and if necessary a third, the object being to form a thin coating or sleeve around the core, which becomes a part of the core itself. As this last coating becomes sticky (as it does just before drying), a piece of pure ruber tape about 3 or 4 inches in length is wrapped on, commencing about a quarter of an inch from the point of the cone, across the bare conductor, and running up to the other cone for about a quarter of an inch; the wrapping is then continued back to the starting point, each turn overlapping the previous one. Now, holding the unused end of the rubber tape with one hand, cover the freshly wrapped rubber with a thin coating of cement, distributing it evenly and quickly, then wrap on another layer of pure rubber. Apply a thin coating of cement over this also. Next wrap on the splicing compound, commencing at the large end of the cone, wrapping over the pure rubber and up to the large end of the other cone, then back again, continuing till the joint has been built up slightly larger than the original core. No cement is used between or over the layers of splicing compound.

Again apply the cement to that part of the core as yet unwrapped, and when ready, wrap onto the core two layers of okonite rubber tape, which will bring that part of the core to the same diameter as the joint; continue the third layer of okonite all the way across the joint, build up the core on that side, then continue back across the joint to the starting point. Touching a warm iron to the end of the okonite will keep it from unwrapping when you let go of it.

Now wrap one layer of friction tape over the joint from end to end, allowing the tape to overlap about half its width each turn, this wrapping to be put on as tight as possible, to act as a compress and binder for the rubber over which it is laid.

Over all of this wrap two layers of P. & B. tape, commencing at one end of the joint; wrap completely across, and then back again to the starting point, occasionally warming the tape with a torch, if necessary, to make it lay on close and even.

The joint is now ready to be warmed up. Apply the flame of the gasoline torch directly to the P. & B. tape, moving the flame back and forth along the top, bottom, and sides of the joint until the insulating compound in the P. & B. tape is melted and commences to drip. Then, for convenience in handling while laying on armor wires, wrap on one layer of friction tape with just enough tension to make it lay on evenly. The joint is now ready for the armor wires to be laid on.

NOTE.—The compound of the P. & B. tape, which is in itself an insulator, will, when melted as above, give sufficient heat to cause the okonite tape to form a rubber sleeve over the joint. The friction tape between the okonite and P. & B. serves the purposes of a form or compress, holding the okonite, which has been wrapped on with some tension, and preventing its opening up, due to its own tension, if the heat should not be evenly applied to all points simultaneously. The pure rubber next to the copper conductor, which is primarily put on for the purpose of preventing possible deterioration of the copper by the rubber compounds, will, when put on as in the above joint, serve as an extra precaution against leakage.

(*l*) The armor wires are then returned to place, which they will easily do if care has been taken in handling them. It will be observed that over 15 feet of the armor from one side will lap over that end from which the armor was not removed.

(*m*) The armor replaced, the wires are then bound in place with several seizings of small galvanized-iron wire tightly and evenly wrapped.

(*n*) The entire splice should then be served with a closely wound layer of spun yarn. The proper way of doing this is with the serving mallet. (See fig. 4–17). Of course, if means are not present to do it otherwise, it should be served by hand.

(*o*) After splicing, the bight should be carefully lowered by small ropes attached to each side of it to prevent straining or jerking the splice.

THE VULCANIZED JOINT.

As previously stated, a well-vulcanized insulation for a joint is always desirable and should be made as follows: The preparation of the cable ends, the joining of copper conductor, the coning of insulation, the application of first layer of pure rubber tape, and the replacing and serving of armor wires should be accomplished identically as just described for the "raw joint," consequently only the remaining insulating of conductor splice will be described in the following remarks.

A 60 per cent rubber compound in the form of tape is wrapped closely, smoothly, and evenly over the pure rubber previously placed, the edges of the former overlapping each other, until the joint has been built up to a slightly larger diameter than the mold in which it is to be compressed and heated. Great care should be exercised in all wrapping to preclude the possibility of air pockets forming beneath the layers. Before being placed in the vulcanizer, a piece of paper should be folded and laid over the joint to prevent compound sticking to mold. After the vulcanization has been completed and the joint removed from mold the edges of paper may be trimmed with shears and then moistened and scrubbed off so joint can be inspected for flaws. In all vulcanizing of joints the compounds placed as just stated are subjected to compression and heated to an even temperature approximating 220° F. for approximately 40 minutes.

There are various ways of accomplishing the above. It is believed that electric vulcanizers which have been used by the Signal Corps on the U. S. Army transport *Burnside* are the most satisfactory apparatus for this work where a source of electric current is available. They are a specially constructed heater equipped with proper resistance for maintaining required temperature for a given voltage. The heater consists of two parts so arranged that when the upper is clamped to lower a groove in upper half comes directly over groove in lower half forming a concentric aperture somewhat larger than the diameter of the cable core and several inches in length. In between these two electrically heated plates is placed the joint to be vulcanized, the upper plate being forced down toward the lower plate by means of a hand screw, which keeps the joint under pressure during the time of vulcanization.

Where it is not practicable to use the electric vulcanizer, such as for portable work, remote from a source of supply of electric current, and it is desired to make the joint as with the electric vulcanizer, the same results can be obtained by the use of two iron blocks each about 2 inches square and 6 or 8 inches in length with a semicircular groove in one side of each block extending the full length, and the blocks so arranged by means of dowel pins, or preferably a shoulder running the full length of both sides of the lower block, to assure the alignment of one groove over the other when the two blocks are placed together. In the top of the upper block a hole is bored of sufficient size and depth to permit of the insertion of the bulb of a thermometer for the purpose of observing the temperature of the blocks. A couple of ordinary iron hand clamps are then used to press the upper and lower blocks together on the joint to be vulcanized, and heat applied with a gasoline torch. By watching thermometer closely any desired temperature can be maintained, as the mass of the iron blocks is sufficient to prevent sudden variations of the temperature.

When the electric vulcanizer or the iron blocks previously described are not available the joint can be vulcanized by using hot paraffin, as follows: After having completed the wrapping of the rubber compound, wrap on over this as tightly as possible two layers of friction tape to act as a binder or compress, extending this wrapper of friction tape well back on the original rubber core so that any part of the original rubber core that may also be in the paraffin during the time of vulcanization will not be exposed. If this precaution is not taken the rubber core itself may be injured. In addition to the friction tape it is advisable to wrap twine tightly over the outside of the joint at the ends where the new rubber compound is wrapped onto the cone shapes of the original rubber core, as it is at these points most difficult to secure that cohesion which is necessary for a water-tight joint. After the joint has been vulcanized and cooled this twine may be cut and taken off.

The paraffin is heated by placing the tray in which it is contained over the flames of a gasoline furnace, and when brought up to the proper temperature, which is determined by means of a thermometer immersed in the paraffin, the joint is then placed in the paraffin and allowed to remain the required length of time. Frequent readings of the thermometer are made during the time of immersion of the joint in order to maintain an even heat. The temperature readings should be taken close to the joint, as under certain conditions there may be a wide range of different temperatures in the same tray.

Where the 60 per cent compound and the time for above is not available, a good water-tight joint can be made by using the pure or " Para " rubber entirely. This rubber cut into strips of about three-fourths inch width should be thoroughly warmed and wrapped on closely and smoothly but not too tightly. If the Para is wrapped on cold and stretched tightly it may be found that when the joint is removed from the heater, the conductor, instead of being in the center, has been forced to one side; and although from outward appearances the joint may appear perfect there may be no more than a thin film of rubber covering one side of the conductor. This possible condition is eliminated by thoroughly warming the rubber before wrapping on, as the rubber will then pull in two before the tension with which it is wrapped on becomes great enough to cause the condition of nonconcentricity as shown above.

The electric vulcanizers which have been furnished the *Burnside* in making joints of this kind give a temperature of 220° F., and allowing the pure or Para rubber joint to remain in these heaters for 15 to 20 minutes at that heat has been found sufficient time to give a good water-tight joint.

In all of the above methods it will be noticed that a considerable length of time and preparation is required for the heating process alone, in addition to which there is the time required for the preparation of the joint before heating, as also the replacing of the armor wires, putting on the seizing wires, and serving over the whole splice with spun yarn.

On the cable ship this element of time is a large factor in determining the kind of joint to be made; especially so has this been the case on the *Burnside* during the last several years, most of the work being in Alaskan waters during the winter months, under the most unfavorable weather conditions, when the successful accomplishment of repairs being made may depend upon the expediency with which the various operations pertaining to the repairs are performed.

SPLICING PAPER-INSULATION SUBMARINE CABLE.

The armored portion of the cable is treated as described for rubber insulation submarine cable, except that extra precaution should be taken in covering the lead sleeve of splice, especially where outside diameter of sleeve reduces to outside diameter of cable sheath. It may be necessary to fill in between armor wires of cable with extra lengths of armor wire, due to enlarged diameter over sleeve, before serving completed splice with spun yarn.

The details of the splice otherwise conform to description for the splicing of all paper-insulation cables appearing later under this subject.

This type of cable is frequently used in underground construction where trenching is resorted to. With such use an alternative method of protecting the splice is to cover it with a 3 or 4 foot length of iron pipe, it being necessary to slip pipe over one end of cable before splicing is started. When this method is employed, the pipe should be left in a position slightly off the horizontal, in order that water will not be apt to stand in pipe. With a well-made joint the only objection to water in pipe is the likelihood of it freezing.

SPLICING OF ALL PAPER-INSULATION CABLES.

Material required.—The following material will be required for each splice:

(*a*) Paper sleeves, or their approved equivalent, for covering the joint in each conductor.

(*b*) Paraffin for drying the splice.

(*c*) Strips of muslin, or its approved equivalent, for wrapping the splice.
(*d*) Lead sleeves.
(*e*) Solder for seams and wiped joints.
(*f*) Gummed paper for limiting the wiped joints.

Before being used the paper sleeves should be immersed in hot paraffin, or otherwise thoroughly dried, until they are entirely free from moisture.

For wrapping the core after splicing and for binding the ends of a splice, strips of muslin, or its approved equivalent, should be used.

Sleeves should be made of the same material of which the cable sheaths are made or of pure lead.

The thickness of the lead sleeve covering the splice shall be one-eighth of an inch when the inside diameter of the sleeve is 3 inches or less, and three-sixteenths of an inch when the inside diameter of the sleeve is more than 3 inches.

The dimensions of sleeves which may be used in splicing cables of various sizes are given in the following tables. Where the cables to be spliced together are not of the same size, the proper sleeve for the largest of the cables shall be used.

Lead sleeves for straight splices.

	No. 19 gauge wire.		No. 22 gauge wire.	
Number of pairs.	Inside diameter.	Length.	Inside diameter.	Length.
	Inches.	*Inches.*	*Inches.*	*Inches.*
15	1	16	1	16
20	1½	16	1	16
25	1½	16	1½	16
30	2	16	1½	16
50	2	16	2	16
75	2½	16	2½	16
100	3	16	2½	16
150	3	18	2½	16
180	3½	18	2½	16
200	3½	18	3	18
300	4½	22	3½	18
400	....	....	3½	22

Lead sleeves for 3-way or "Y" splices.

	No. 19 guage wire.		No. 22 gauge wire.	
Number of pairs.	Inside diameter.	Length.	Inside diameter.	Length.
	Inches.	*Inches.*	*Inches.*	*Inches.*
10	1	16	1	16
20	1½	16	1½	16
25	1½	16	1½	16
30	2	16	2	16
50	2½	16	2½	16
75	3	16	3	16
100	3½	18	3½	18
150	4	18	4	18
180	4½	18	4	18
200	4½	22	4	18
300	4½	22	4½	22
400	....	....	4½	22

For splicing cables with larger conductors than are given in the tables, sleeves may be used of which the length is about eight times the outside diameter of the cable and of which the inside diameter is about 50 per cent greater than the outside diameter of the cable.

So far as possible, splices should be finished and soldered the day they are begun. Where necessary, if the surroundings be dry, an unfinished splice may be left open overnight provided it be carefully wrapped and protected from moisture by a rubber blanket or other suitable covering. In wet or damp surroundings, however, work on a splice should be continuous until finished. In such cases the splice should be "boiled out" with paraffin at intervals—say, after each 50 pairs have been connected.

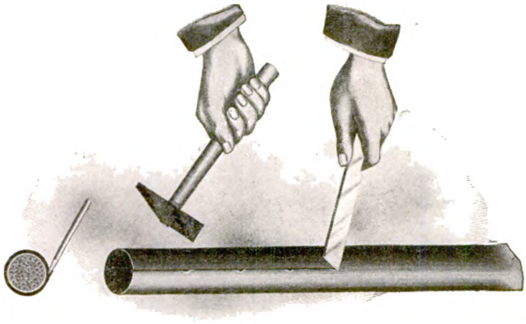

Fig. 4-18.—CABLE, PAPER INSULATION, SPLICING.

Whenever it may be necessary to leave the cable end it should be thoroughly dried and sealed with solder, as much care being taken as if the joint were to be permanent.

If it is suspected that moisture has entered the end of a cable, a short length of it should be cut off and dipped into hot paraffin, when the presence of moisture will be indicated by a characteristic frying sound. If there is length to spare, the cable should be cut back, a short portion at a time, until it gives no evidence of dampness.

After this the end should be thoroughly dried with paraffin and a splice made or the end sealed, as already described.

The operations of making a straight splice in their sequence are as follows:

1. After being sure that no moisture exists in either of the cable ends to be spliced, remove the lead sheath from each end for a distance equal to the length of the lead sleeve used.

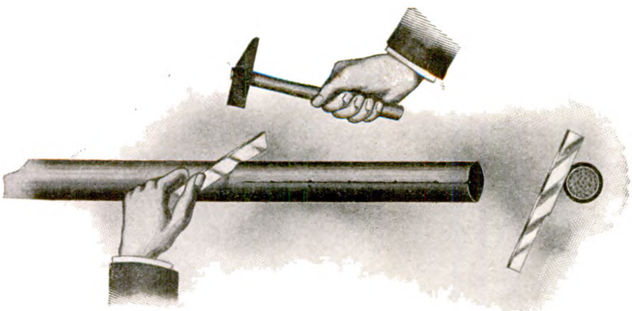

Fig. 4-19.—CABLE, PAPER INSULATION, SPLICING.

In removing the sheath care must be taken not to injure the insulation of the wires. (Figs. 4-18 and 4-19.)

2. The core is tightly bound with strips of muslin, or its approved equivalent, at the end of the cable sheath, packing the binding close to the sheath. This is done to prevent the wires from being cut on the edge of the sheath. (Fig. 4–20.)

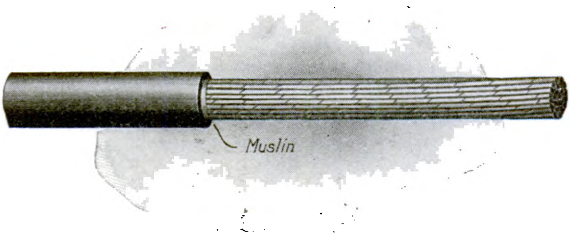

Fig. 4–20.—CABLE, PAPER INSULATION, SPLICING.

3. In general, as soon as possible after the removal of the lead sheath the exposed conductors are thoroughly "boiled out" by pouring hot paraffin over them until all traces of moisture are removed. The binding must be saturated with paraffin as well as the core. Enough paraffin remains in the core to form a seal, which protects the cable against moisture while the splice is being made. The temperature of the paraffin should be above that of boiling water, but must not be high enough to scorch or make brittle the paper insulation.

In drying or "boiling out" a splice with paraffin, always work away from the cable sheath toward the end of the conductors or middle of the splice in order to prevent any moisture being driven under the sheath. The paraffin should be poured on with a ladle. The paraffin draining off may be caught in the melting pot or a pan

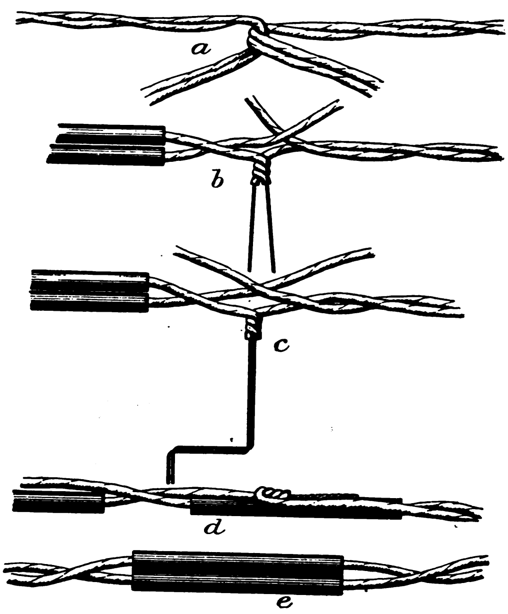

Fig. 4–21.—CABLE, PAPER INSULATION, SPLICING.

4. The ends of the cable sheaths and of the lead sleeve should be scraped bright for 3 or 4 inches and rubbed with tallow, or its approved equivalent, to keep them clean during the subsequent work on the splice. The tallow also acts as a flux in making the wiped joints.

5. The lead sleeve is next slipped over the end of one cable and moved back out of the way.

6. The two cables are placed and firmly secured in the same straight line, with the distance between the ends of the sheaths about 3 inches less than the length of the lead sleeve.

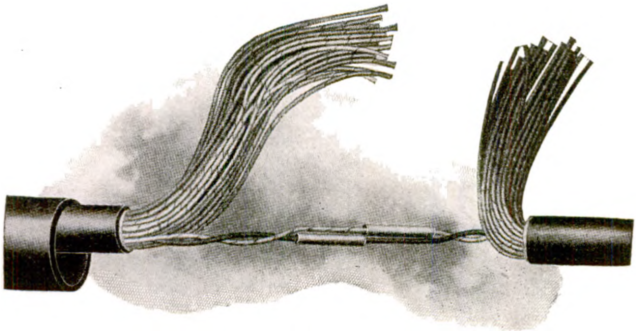

Fig. 4-22.—CABLE, PAPER INSULATION, SPLICING

7. After the cables are in position the conductors are bent out of the way and shall then be spliced in the following manner:

8. Starting at the center or the lower back side of the cables, a pair of wires from each cable is loosely brought together with a partial twist (*a*, fig. 4-21), thus marking by the bend in the pairs the point at which the joint is to be made. Slip a paper sleeve over each wire of one pair and push the sleeves back far enough to allow room for making the joint.

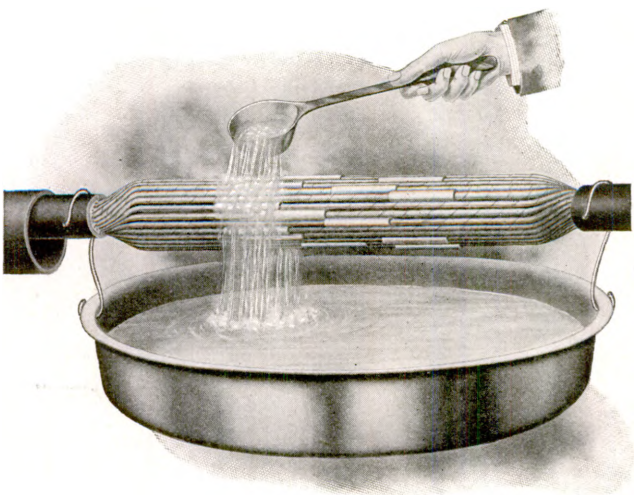

Fig. 4-23.—CABLE, PAPER INSULATION, SPLICING.

The wires are now to be connected by a splicer's ordinary twist joint (*b*, fig. 4–21). The like wires from the two pairs to be spliced are brought together at the point marked by the bend and given two or three twists (*c*, fig. 4–21). Remove the insulation of both wires beyond the twist, being careful not to nick or scrape the conductors. The wires are now to be bent as

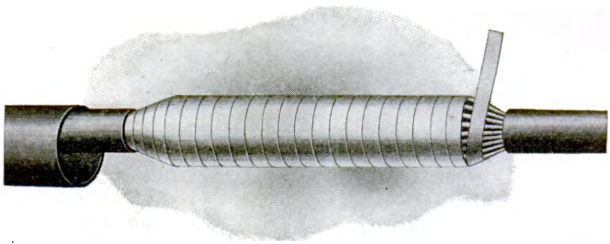

Fig. 4–24.—CABLE, PAPER INSULATION, SPLICING.

shown and twisted together as if turning a crank. This action insures good contact even though the wire may be coated with a film of paraffin due to the "boiling out" process. The ends are cut off, so as to leave the twist of bare wire not less than 1 inch in length. The twist is bent down along the insulated wire and the paper sleeve slipped over the joint (*d*, fig. 4–21). The completed joint, with the sleeves in place, is shown in *e*, figure 4–21.

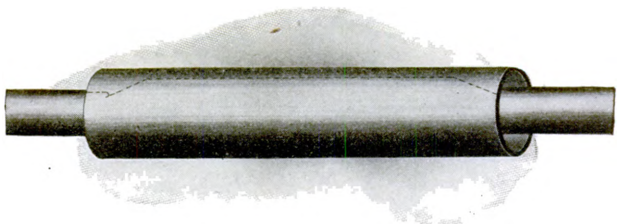

Fig. 4–25.—CABLE, PAPER INSULATION, SPLICING.

For conductors of large size (No. 13 B. & S. gauge or larger) the wires may be joined by means of a Western Union Telegraph joint or other approved method. The joint is covered with a paper sleeve.

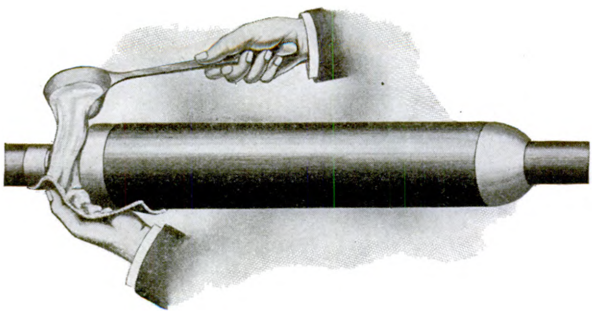

Fig. 4–26.—CABLE, PAPER INSULATION, SPLICING.

In splicing, care should be taken to splice the center and lower pairs first, forming the outer pairs about the center pairs so that the finished splice may have a uniform shape.

In picking out the pairs to be spliced together care should be taken to transpose the circuits thoroughly. It is sufficient if the transposing be done between pairs in the corresponding layers of the two cables.

The wire joints should be distributed along the whole length of the splice in order to keep the splice uniform in size and shape.

9. When all the wire joints have been made, the splice is again "boiled out" with hot paraffin until all traces of moisture have been removed. In applying this paraffin, work from the ends of the splice toward the middle.

10. The splice is then wrapped with strips of muslin, or its approved equivalent, and compressed until the lead sleeve will just slip over the splice. Care must be taken not to compress the splice too tightly or the wires may be forced through the insulation and crosses in the splice result.

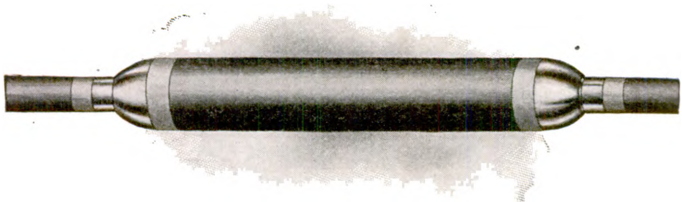

Fig. 4–27.—CABLE, PAPER INSULATION, SPLICING.

The splice is dried out with hot paraffin after the first wrapping of muslin has been put on and again after the wrapping of the splice is complete. The drying out is continued until bubbles cease to appear on the splice.

11. The lead sleeve is slipped into place before the splice has had time to cool, taking care, however, to see that the sleeve is perfectly dry.

The ends of the sleeve, which should overlap the cable sheath at each end by about 1½ inches, are beaten down to conform to the cable sheath and a wiped joint carefully made at each end. In making the wiped joints strips of gummed paper may be used to limit the joints.

Wiped joints should be carefully inspected, using a mirror when necessary to detect any imperfections in the seal.

THREE-WAY OR "Y" SPLICES.

The method of making a three-way or Y splice is the same as for a straight splice except in the following particulars:

There are two general classes of Y splices—

1. Where the cables all end at the splice.
2. Where a branch cable is to be spliced into a continuous cable.

In the first case the method is generally similar to a straight splice. The sheaths of all three cables are removed for a length equal to the length of the lead sleeve. The two cables forming the main cable are secured in a straight line with the distance between the ends of the sheaths about 3 inches less than the length of the sleeve. The branch cable is lashed beside one of the main cables with the end of its sheath opposite the end of the sheath of the main cable.

The joint is made by twisting together like wires of pairs from each of the three cables, taking care to include two or three twists of the insulation in the joint in the manner hereinbefore described for straight splicing.

The lead sleeve in this case may be a whole sleeve. It should be slipped on and pushed back on that portion of the main cable away from the branch.

In the second case a split lead sleeve must be used.

The sheath of the main cable shall be removed for a length of about 3 inches less than the length of the sleeve. The sheath shall be removed from the end of the branch cable for an equal distance.

The branch cable is lashed to the main cable, with the end of the sheath opposite the end of the sheath of the cable.

A pair of conductors in the main cable is cut. To one end of each conductor is spliced a short piece of bare wire of the same size as the cable conductors. This wire should be twisted into the insulation two or three times, in order to prevent its pulling back on the conductors. The second end of the main conductor, the free end of the bare wire, and a like conductor of a pair in the branch cable are twisted together, in the manner already described, and covered with a paper sleeve which is long enough to cover both ends of the bare wire.

If there is slack enough in the main cable, the joint may be made without splicing in the bare wires.

In putting on a split lead sleeve the seam must be carefully soldered, then the ends beaten down to conform to the sheaths of the cables and soldered with wiped joints at each end. Care should be taken to retouch the ends of the seam after the wiping is complete, in order to make sure that the seam has not been opened while the wiping was in progress.

A grooved wooden block should be placed in the fork of each Y splice, in order to keep the cables apart. This block is kept in place and the cables at the same time protected from the possibility of too great a separation by means of a wrapping of wire soldered to the cable sheaths.

POT HEADS.

It will readily be seen that it is impracticable to connect to terminals, conductors of a cable wrapped with manila paper. Where it is desired to terminate such a cable, a rubber-covered wire is spliced to each conductor. A lead sleeve fastened to lead sheath of cable by means of "wiped joint" is used to house such splices and also as a container for an insulating moisture repellant compound, which is poured as hereinafter described.

METHOD OF MAKING A POT HEAD.

This description covers the method of making a flexible cable terminal or pot head for terminating the conductors of a lead-incased, dry-core, paper-insulation cable, with rubber-covered conductors, and at the same time effectually sealing the lead-incased cable against the ingress of air and moisture.

The lead sleeve or pipe of this terminal should have a length of eight times the outside diameter of the cable to which it is to be attached, plus 10 inches, and an outside diameter of at least one and one-half times the outside diameter of the lead cable. The lead sleeve should have a thickness not less than that of the sheath of the lead cable.

The wires of this terminal, which are to be spliced to those in the lead cable, should be covered with okonite insulation or its approved equivalent. The rubber-covered wires may be loose or in the form of a taped cable, and should be of the size and length required. The Signal Corps supplies a rubber-insulation twisted pair wire, known as pot-head wire, for the purpose when loose wires are employed.

All tape used in the terminal should be adhesive or rubber tape of the best quality.

The paper or cotton sleeves used should be of the ordinary form for covering wire joints in paper-insulation cable.

The tube for adding the compound to the terminal should have an inside diameter of one-half inch and a length 2 inches less than that of the lead sleeve. The tube should have thin walls and may be made of metal, vulcanized fiber, or manila paper rolled about a half-inch rod and bound thereto with string.

While the use of this tube is desirable it is not necessary if great care is taken to have the compound reach bottom of sleeve.

The sole leather should be approximately three-sixteenths of an inch in thickness, 3 inches in width, and long enough to wrap once about the taped cable or rubber-covered wires.

Heavy cotton twine or wicking should be used for binding purposes.

The wiping solder used should be the commercial plumber's wiping solder, which is composed of 60 per cent lead and 40 per cent tin. It is sometimes advisable to add a slight amount of half and half solder (50 per cent lead and 50 per cent tin) to slightly increase the proportion of tin. The latter is decided by the action of the alloy.

The sealing compound should be of any approved waterproof, semielastic, insulating material, which, when melted, will flow readily into the lead sleeve and about the wires and adhere tenaciously to the wires and lead sleeve. The compound should not be sufficiently affected by the conditions of exposure as to endanger the seal.

No. 1 ozite is the compound most commonly used.

DIRECTIONS FOR SETTING UP THE POT HEAD.

[See fig. 4–28.]

No paraffin shall be used in "boiling out" cable ends and sleeves for pot heads.

The proper amount of sheath should be removed from the lead cable, the lead sleeve slipped over the cable, and the cable wires spliced to the rubber-covered wires in the usual manner, using paper or cotton sleeving.

In doing this work care must be taken to remove all pieces of paper, jute, tape, or other things which might obstruct the flow of the compound, which is to be poured in after the lead sleeve is in place.

Close to the end of the lead cable sheath the paper-insulated wires should be tightly wound with a number of layers of twine or wicking in such a manner as to prevent the compound from entering the cable.

If rubber-insulation cable is used for extending the conductors of paper-insulation cable, the preceding remarks are applicable and the outer braid or covering of the rubber cable should be removed in order that the conductors may separate. About 1½ inches of the cable, with braided or other covering, should enter the sleeve.

At that point on the rubber-covered wires or rubber-insulation cable which will come immediately at the end of the lead sleeve should be wrapped, first, a single layer of sole leather, and over this several layers of adhesive or rubber tape. The leather should enter the finished splice about 1½ inches and project the same distance.

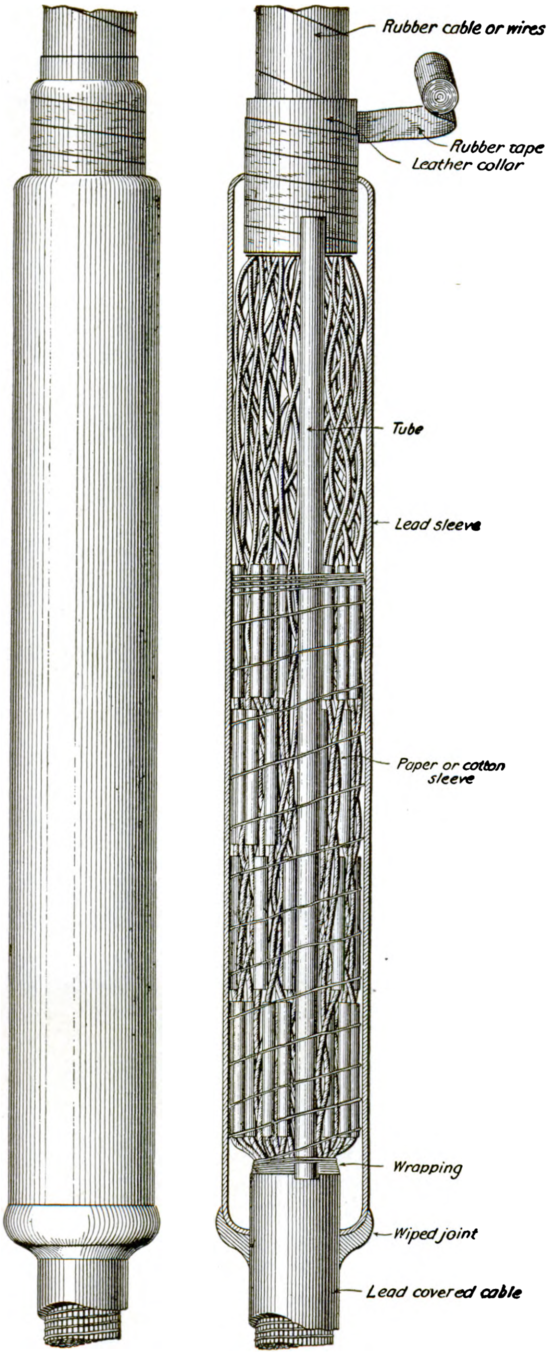

Fig. 4–28.—CABLE, PAPER INSULATION, CONSTRUCTION OF POT HEAD.

The entire splice should next be opened up as much as possible in order that the sealing compound may flow readily about every wire. If a hemp cord be found in the rubber cable it should be cut off as close as possible to the cabled portion.

The one-half inch tube should then be laid along in the splice with one end on a line with the end of the lead cable sheath and fastened in position with several turns of twine. This twine serves the double purpose of keeping the tube in place and reducing the splice to a diameter which will allow the lead sleeve to be drawn on without disturbing the sleeves covering the spliced wires. The turns of twine should not extend beyond the last of the wire joints on the rubber-covered wire end of the splice. It should not be drawn too tightly but should allow the compound a chance to get to the wire. If the manila-paper tube is used, the rod on which it is rolled should be retained in the tube until the splice is ready to be filled.

The lead sleeve should be drawn over the splice, allowing it to project over the lead cable sheath 1½ inches, and then connected to the lead cable sheath by means of a "wiped" joint.

The lead cable sheath, with sleeve attached, should now be fastened in an upright position, the sleeve warmed until it becomes barely possible to touch it with the hand, and the sealing compound heated to as high a temperature as is possible without burning the insulation from the wires, slowly and cautiously poured in through the tube, using a funnel to assist in the operation. The compound should fill the sleeve to within one-half inch of the top. When the compound cools sufficiently, more should be poured in at the top of the sleeve, the tube not being used.

After the splice has become thoroughly cold the open end of the lead sleeve should be carefully dressed into contact with the taped leather which surrounds the rubber-covered wires or cable.

If possible the pot head should be mounted in an upright position. When it is necessary in inside construction to place the pot head in a horizontal position, the open end of the lead sheath should be wrapped with tape to prevent the compound from running out, and care should be taken to locate the pot head where it will not be exposed to excessive heat.

Rubber-insulation lead-sheath cables are sometimes furnished with pot head where they terminate in a subterranean cable terminal box or other apparatus not supplied with a means of sealing the cable.

The placing of pot head on this type of cable is a comparatively simple operation, pot head being merely for the purpose of sealing the cable to prevent moisture entering it. A short lead sleeve is placed as described under pot heads for paper-insulation cable, the conductors of cable extending beyond sleeve sufficient distance to permit of being laced into forms and connected to terminal strips. The sleeve is then filled with a suitable sealing compound. When the compound cools, it will be necessary to again fill the pot head, as all compounds shrink perceptibly upon cooling.

SUGGESTIONS IN REGARD TO SPLICES.

In branching a small lead-covered cable from a flexible splice or pot head it is considered advantageous to run it out at the base of the lead sleeve, making a double-wiped joint, rather than to run it out with the rubber-covered wires or taped cable.

Should occasion arise when it becomes imperative to shorten the length of the lead sleeve, a sleeve of a greater diameter than is ordinarily recommended should be selected and the space occupied by the joints in the wires contracted, keeping the space between the last wire joint on the rubber-covered wire end and the leather wrapping the same as it would be in a regular splice, this being the space where the efficiency of the seal is maintained.

The sealing compound should rise at least one-half inch above the top of the paper tube.

SPLICING RUBBER-INSULATION LEAD-COVERED SUBTERRANEAN CABLE.

(Types 213 to 216, inclusive.)

Materials and tools required are:

Pure rubber.
Rubber cement.
Adhesive tape.
Gasoline.
Sandpaper.
Solder, resin core.
Solder, wiping.
Lead sleeves.
Cable splicers chest.

The subterranean splice should be made as follows:

(*a*) Slip the lead sleeve over one end of the cable.

(*b*) Conductors must be thoroughly cleaned without the use of acid soldering flux.

(*c*) The insulation must be trimmed cone shaped down to the conductor. Fan out strands, interlace them, and make a Western Union joint (see fig. 4–17). The central conductor may be removed if the joint is large.

(*d*) The very slightest touch of resin flux should be used. Use very little solder. Do not allow resin to touch rubber surfaces. Keep the rubber clean.

(*e*) File off all projecting points of solder on conductor.

(*f*) Wrap the joint after treating with rubber cement with pure Para sheet rubber cut in strips one-half inch in width and wind, overlapping spirally. Continue winding back and forth until a little beyond each of the coned ends and until the thickness of the joint slightly exceeds the original insulation. Rub a clean, warm iron toool over the joint until the rubber fuses slightly. Wrap a double thickness of adhesive tape. Rub warm tool over the finished joint, taking care not to overheat.

(*g*) In splicing multiple-conductor cable, joints in pairs should be slightly staggered.

The lead sleeve is then placed in position and a "wiped" joint carefully made at each end. In making the wiped joints, strips of gummed paper may be used to limit the joint.

SPLICING OF RUBBER-INSULATION LEAD-COVERED AND ARMORED SUBTERRANEAN CABLE.

(Types 217 and 218.)

Material required the same as that previously enumerated for splicing rubber-insulation lead-covered subterranean cable, and in addition a ball of marline and small coil of 51 mils diameter galvanized-iron wire.

(*a*) Cut one cable at the point where the splice is to be located.

(*b*) The other cable should overlap the first by about 3 feet.

(*c*) Wrap the shorter cable tightly with soft iron wire at a point about 18 inches from its end.

(*d*) Remove the armor from the end of the shorter cable with a hacksaw and unwind the jute.

(*e*) Cut off lead armor at a point about 10 inches from the end.

(*f*) Wrap the longer cable tightly with soft iron wire at a point 18 inches back of where splice will occur.

(*g*) Cut away the jute and unwrap the armor wire back to the point where the cable has been wrapped.

(*h*) Slip on the lead sleeve.

(*i*) Proceed with joint as described under lead-covered cable.

(*j*) Serve layer of jute or marline over joint.

(*k*) Serve armor wire over joint and onto the short cable and wrap with bare soft iron wire at its end.

(*l*) Serve layer of marline over the outside of replaced armor.

When these splices are made in manholes, the armor does not need to be served over the joint. For permanent trenched cable this should be done.

As an alternative the joint may be covered with a 3 or 4 foot length of iron pipe, it being necessary to slip pipe over one end of cable before the splicing is started. When this method is employed, the pipe should be left in a position slightly off the horizontal in order that water will not be apt to stand in pipe. With a well-made joint the only objection to water standing in pipe is the likelihood of it freezing.

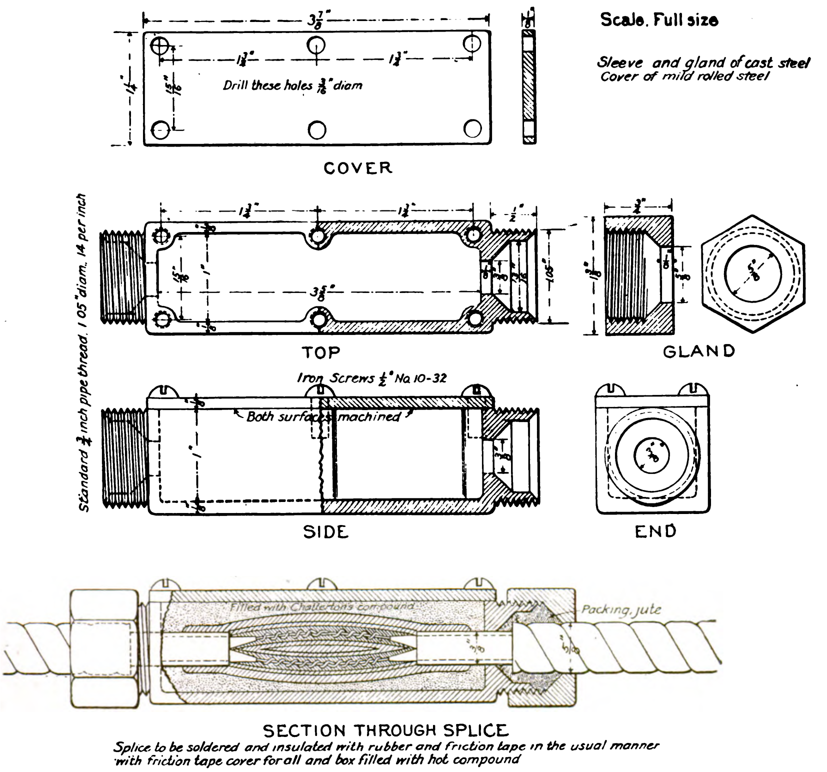

Fig. 4–29.—CABLE, TYPE 251, SPLICING SLEEVE.

In splicing Signal Corps type 251 cable the usual lead sleeve may be used, but it is impracticable to make a wiped joint, due to small diameter and thinness of the lead sheath of this cable, consequently the conductors should be spliced and taped as previously described for conductors of rubber insulation cable and the lead sleeve formed to bind the armor of the cable at either end. By means of holes through side of sleeve near each end the sleeve is then filled with melted Chatterton compound and the holes sealed tightly by means of solder applied with a soldering iron.

Another method of splicing this type of cable makes use of a manufactured splicing sleeve designed for this purpose. It is shown in figure 4–29 and is there described in detail to such an extent that further description would be superfluous.

TESTS OF SUBTERRANEAN CABLES AFTER THEY HAVE BEEN PULLED IN DUCTS AND SPLICED.

Practically all cable purchased by the Signal Corps is inspected during manufacture by an experienced inspector detailed for that work exclusively. The duty of this inspector is to watch closely the various operations at the factory and to make all prescribed tests of material mentioned in the specification. He should do all in his power to facilitate the manufacture, but his paramount duty is to see that workmanship is of highest class, that materials used meet all prescribed tests, and that the general intent of the specification describing cable being manufactured is adhered to. Results of the more important tests are recorded and a copy of this record forwarded to the Chief Signal Officer of the Army, who has it placed in the archives, where it may be referred to should occasion for such action arise. A tag bearing order number, inspector's initials, and date of acceptance is attached to reel. This tag is in addition to brass tag bearing Signal Corps number, which has previously been described.

In view of the above it is safe to assume that new cable is of the best quality, everything considered, and it only remains necessary to install and splice it properly in order that this very important part of an electrical system will be of the highest standard.

If any recovered cable is furnished, a preliminary test of it before installation should be made, and cable that does not appear to be in excellent condition mechanically or electrically should not be used.

After the cables have been pulled in ducts and splices and pot heads placed, the person in charge of the installation or an assistant will test each completed cable. Each conductor is assigned a number. The tests of the completed cable will show insulation resistance of each conductor, electrostatic capacity of each conductor, and ohmic resistance of each conductor. When tests are made the tester carefully records data obtained in a field book and when convenient computes values and enters them on Signal Corps Blank Form No. 261, issued for the purpose.

With cables of short length it is difficult to obtain readings, due to high value of insulation and low value of electrostatic capacity, and therefore it is not necessary that actual values be recorded. A statement in effect that each conductor has an insulation equal to 500 megohms per mile or that the tester was unable to obtain deflection on the galvanometer will be sufficient.

Ohmic resistance of conductors should be recorded.

These tests will disclose the condition of each completed cable of the system and will show whether or not defective splices or pot heads have been made; also whether or not the cable has been injured in pulling it into the conduits. This is especially true if the cable has been subjected to moisture, due to rain or otherwise, after all splices have been completed. The reason for this is obvious, as it can be readily understood that a hole in the lead sheath would not affect the insulation resistance of a cable if the cable at that point is kept absolutely free of moisture.

The exacting methods employed in making the factory test should be ignored in making this field test. This means that no correction should be made for temperature or for the one-tenth megohm resistance usually left in series with insulation resistance being measured.

Corrections, however, should be made for insulation, capacity, and ohmic resistance of leads if it is found that ultimate values are materially affected by these values.

For accomplishing the tests just mentioned the Signal Corps issues an electrical instrument case.

The contents of this case are as follows:

ELECTRICAL INSTRUMENT CASE.

[This instrument case is manufactured under specification No. 145.]

CONTENTS.

One insulation and capacity test set, consisting of the following in case:

1 portable galvanometer of the D'Arsonval type, conforming to that shown in figure 4–30.
1 telescope and scale for above galvanometer.
1 100,000-ohm box.
1 combined shunt and switch.
1 condenser set.
1 ohmmeter.
1 tripod, external to case.
1 service testing battery, drawing No. 199*b*, specification No. 185.
1 micrometer caliper, without ratchet stop, with morocco carrying case.
1 inspector's pocket tool kit, as per drawing No. 204, specification No. 186.
1 testing telephone.
1 space for forms and reports.
1 space for books.

MISCELLANEOUS PARTS AND SUPPLIES.

1 galvanometer coil and mirror.
4 round-head plugs.
6 lower suspensions.
6 upper suspensions.
2 milled-head screws.
1 piece felt.
4 screws for glass.
1 ohmmeter card.
1 piece chamois.
1 bottle vaseline.
1 bottle typewriter oil.
100 feet No. 22 bare copper wire.
100 feet advance wire, No. 28.
25 feet No. 22 manganin wire.
150 feet No. 34 manganin wire.
300 feet No. 40 manganin wire.
60 feet No. 28 manganin wire.
1 glass window.
4 paper scales.
6 feet battery cord.
10 feet okonite wire.
8 ounces solder.

REPAIR KIT.

The repair kit contains the following instruments:

1 nickel-plated screw driver.
2 pairs tweezers, nickeled.
3 lower suspensions for galvanometer.
4 upper suspensions for galvanometer.

Description of the various instruments follows.

THE GALVANOMETER.

A reflecting D'Arsonval galvanometer is supplied, arranged for mounting on a tripod. It is provided with a short insulated telescope arm and an optical system, which magnifies the image of the scale. Owing to this magnification, it is necessary to mount the instrument on a solid floor or to provide against jars while testing, which tend to make the image indistinct.

As in all the instruments of this type, the frame forms conductor for one side of the circuit, and the tripod legs should be wiped thoroughly dry before making a test. This precautionary measure should always be taken.

The sensibility of this instrument is 300 megohms. This is determined by the fact that one volt through one megohm will deflect the mirror 300 scale divisions. Figure 4–30 shows the construction of this instrument.

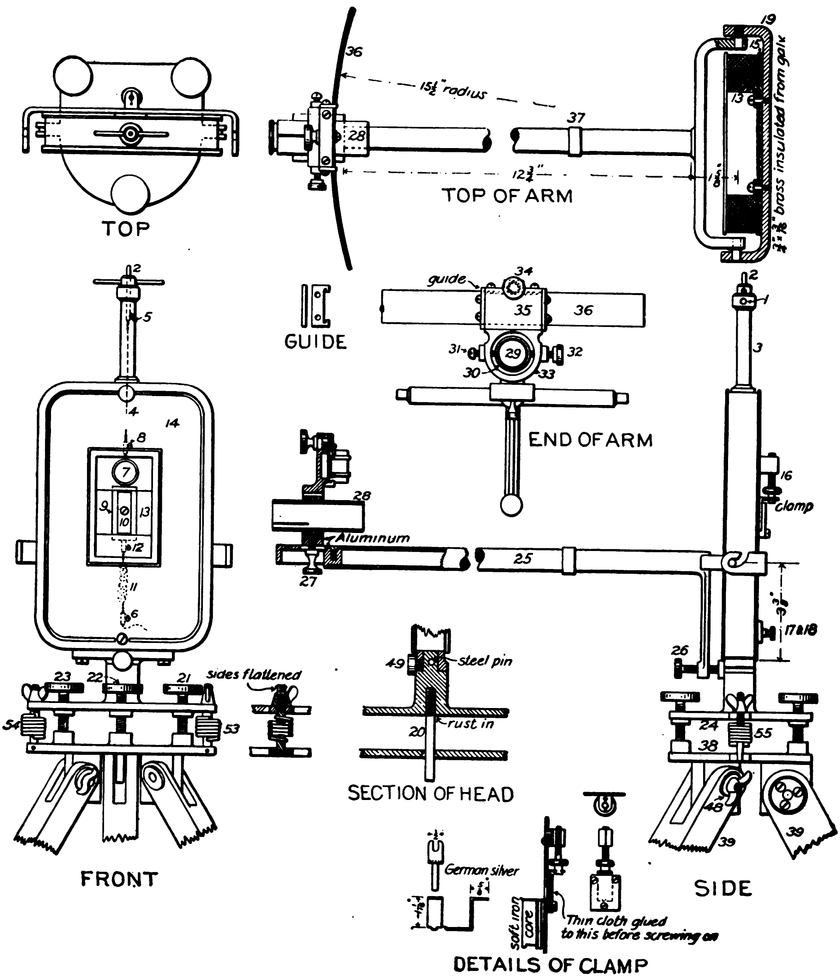

Fig. 4–30.—GALVANOMETER, REFLECTING, D'ARSONVAL TYPE.

(See fig. 4–30.)

Part No.	Name.	Reference No.
1	Torsion head and screw	1
2	Torison rod	2
3	Tube	3
4	Upper suspension	4
5, 6	Suspension heads	5, 6
7	Mirror	7
8	Upper chuck and screw	8
9	Coil	9
10	Magnetic core	10
11	Lower suspension with heads	11
12	Lower chuck and screw	12
13	Field magnet	13
14	Front cover and screws	14
15	Rear cover and screws	15
16	Dampening device	16
17, 18	Terminals	17, 18
19	Telescope rest and screws	19
20	Steady pin	20
21,22,23	Leveling screws	21, 22, 23
24	Base	24
25	Telescope arm	25
26	Arm screw	26
27	Telescope screw	27
28	Telescope barrel	28
29	Lens	29
30	Diaphragm	30
31, 32	Trunnion screws	31, 32
33	Telescope frame	33
34	Scale-adjusting screw	34
35	Scale frame	35
36	Scale	36
37	Insulating joint	37
38	Tripod head	38
39	Upper legs, tripod	39
40	Lower legs, tripod	40
41	Clamp	71
42,43,44, 45,46,47	Clamping screws	42, 43, 44, 45, 46, 44
48	Wing nut	48
49	Base screw	49
50,51,52	Spurs	50, 51, 52
53,54,55	Hinge screws and springs	53, 54, 55

100,000-OHM BOX.

The 100,000-ohm box is a circular rubber case having mounted therein 10 coils wound with No. 40 B. & S. manganin wire. Should trouble occur with this device the proper-sized wire will be found in the spare-parts case. This box is held together with two screws. (Fig. 4–31.)

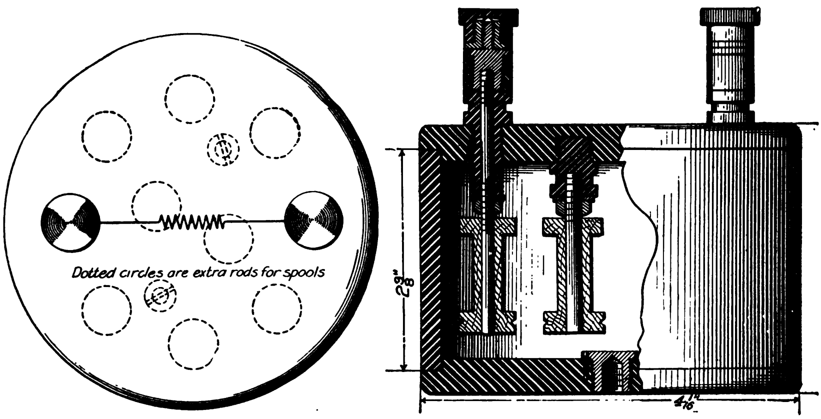

Fig. 4–31.—BOX, 100,000 OHM., STANDARD.

COMBINED SHUNT AND KEY.

This shunt and key, or button, takes the place of the usual Ayrton shunt, battery key, and short-circuit key. Its connections and general construction are shown in figure 4–32.

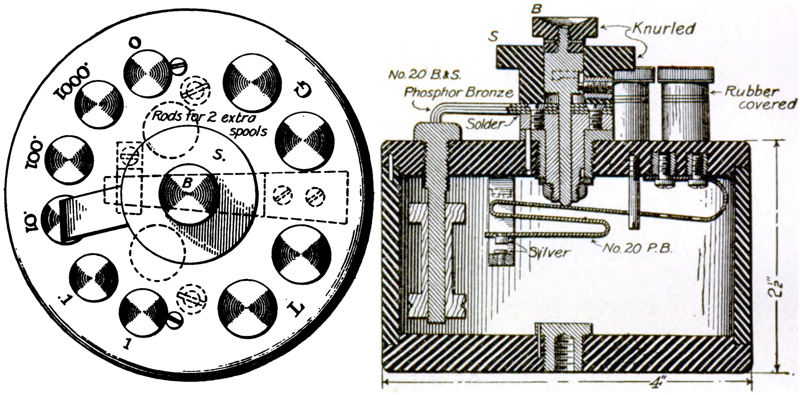

Fig. 4–32.—SHUNT AND KEY.

The key is provided with a bayonet joint. The shunt should always be on 0.0001 at the beginning of the reading, and the lower button is then turned until a readable deflection is obtained.

The button *B* controls the battery, and the button *S* controls the shunt.

This method of operating the galvanometer insures against sudden heavy currents and consequent violent disturbance of the moving system incident to low insulation and dispenses with the short-circuit key.

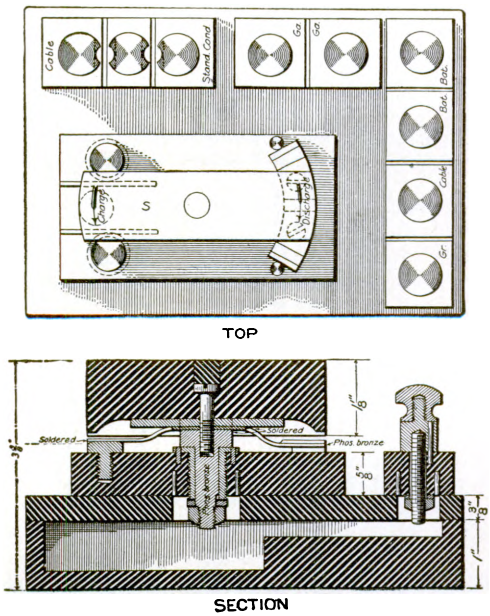

Fig. 4–33.—CONDENSER, STANDARD.

STANDARD CONDENSER.

The standard condenser set consists of a one-third microfarad nonadjustable condenser, with a key for its operation, and the necessary binding posts and plugs, as shown in figure 4–33. Its connections are also shown in the figure. By moving the switch *S* to the right either the cable or condenser may be charged, depending on the location of the plug. The condenser is of best-grade mica, with resin and beeswax filling.

SERVICE-TESTING BATTERY.

The service-testing battery consists of 100 cells of small dry batteries. (Fig. 4–34.) They should be examined once a month.

The battery is tapped for 5, 10, 25, 50, 75, and 100 cells. When new it should have an E. M. F. between 140 and 150, and should not drop below 100 within a year. When certain cells show deterioration they should be removed and the circuit restored. New cells throughout should be requisitioned for when a majority of the cells show discoloration and the voltage of the whole battery is under 80 with all connections in good order and the poorest cells cut out.

Care must be exercised to keep the battery connections clear of short circuits, as the total high voltage will cause a heavy current to flow and ruin the battery very quickly if connected to a circuit of low resistance.

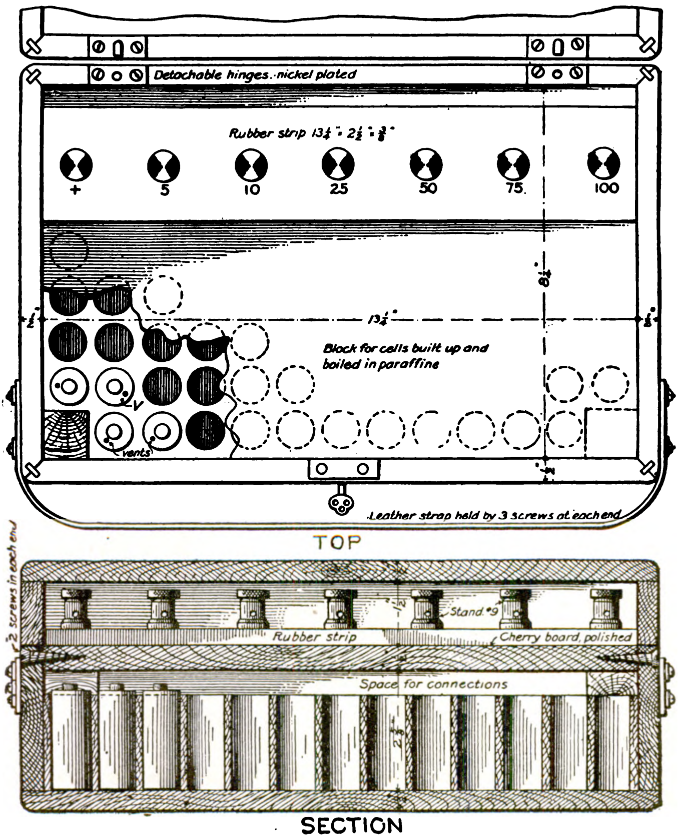

Fig. 4–34.—BATTERY, SERVICE, TESTING.

OHMMETER, MODEL 1904.

The ohmmeter furnished with this case is a compact form of the original model ohmmeter. The variable resistance is wound on a cylinder so arranged as to be divided into 1,000 equal parts by a horizontal scale of 20 equal parts and a

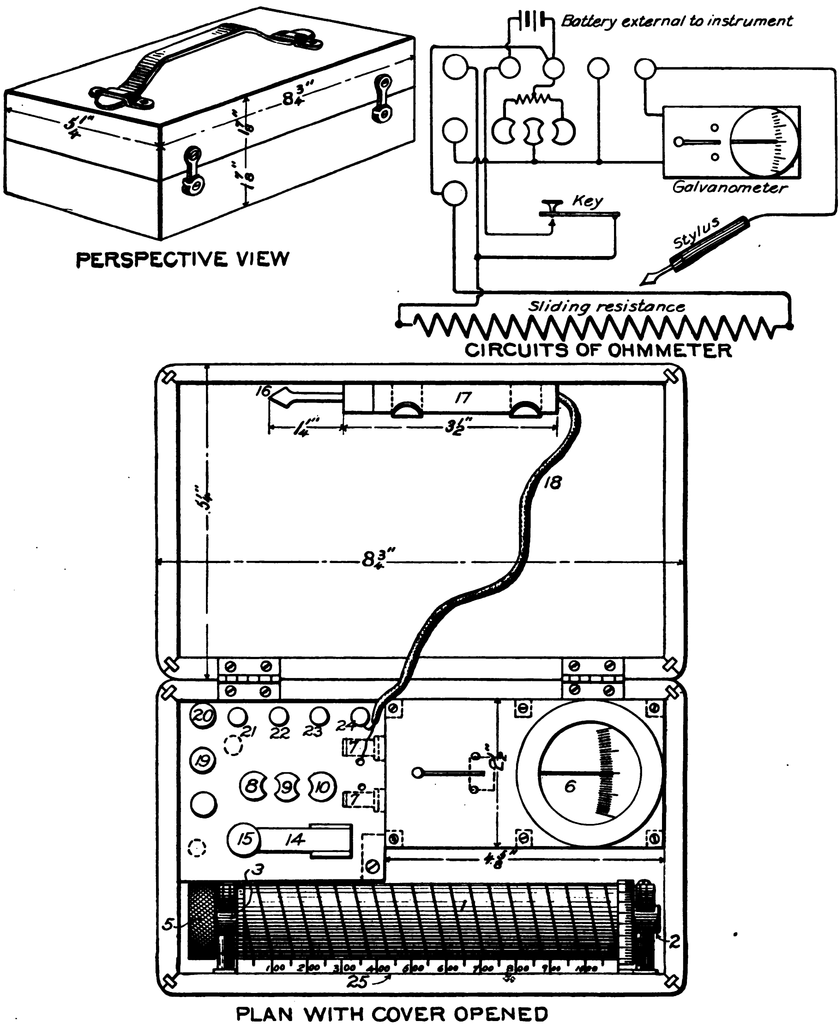

Fig. 4–35.—OHMMETER, MODEL 1904.

drum scale of 50 unit parts. The reading obtained from the stylus is arbitrary, and reference is had to the table in the cover of the instrument for the actual resistance corresponding to any given position of the stlyus. (See fig. 4–35.) The battery key has a bayonet catch.

CABLE-TESTING TELEPHONE.

This telephone was designed in the engineering division, Signal Office, for use of cable testers, and, as will be noted, is especially arranged for this work. (See figs. 4–36 and 4–37.)

The home station is provided with four cells of 4–0 battery, a pony relay, a buzzer, a choke coil, an interrupter, and a hand set. The distant station has a hand set and a resistance of 500 ohms normally in circuit with it, but this resistance may be cut out by depressing the switch in the handle of the set.

When the home operator wishes to call the distant station he draws out the ring of the interrupter, which causes the distant receiver to rattle. When the distant operator picks up his hand set and closes the switch in the handle, short-circuiting the 500 ohms at the distant telephone, the home relay operates, closing a local buzzer circuit and causing the buzzer to vibrate. When the home operator depresses his switch in the hand set, the buzzer is cut out of circuit and conversation may take place. The distant hand switch is used for calling only.

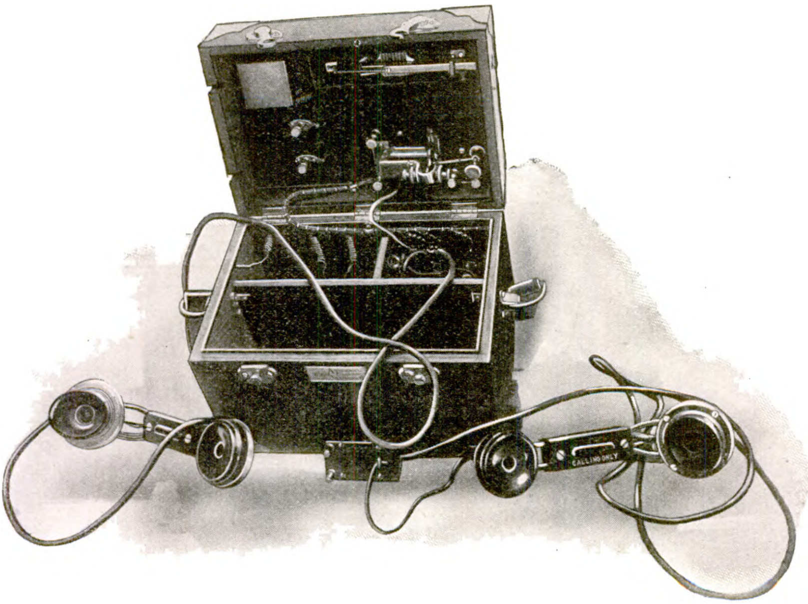

Fig. 4–36.—TELEPHONE, CABLE TESTING.

Part No.	Name.	Reference No.
1	Case	....
2	Battery (4 cells of 4–o)	....
3	Pony relay	....
4	Buzzer	....
5	Choke coil	....
6	Interrupter	....
7	Hand set, home station (switch in handle)	....
8	Hand set, distant station (switch and 500 ohms in handle)	....
9	Cord for hand set	....

METHOD OF MAKING FIRST TEST AFTER INSTALLATION.

The tester should have two assistants. One should be a man familiar with electrical apparatus. The cable tester should proceed to a point from which a number of cables radiate. The more experienced assistant should be sent to distant end of cable.

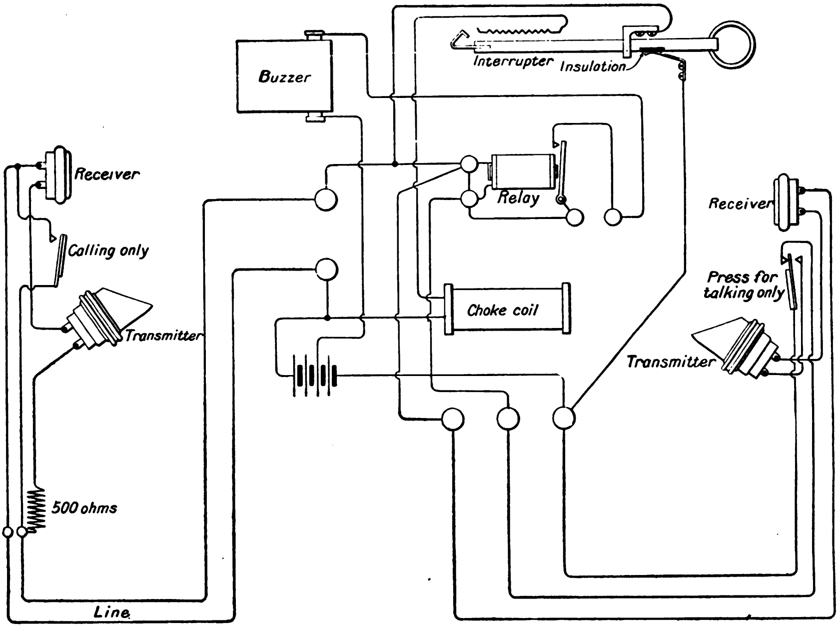

Fig. 4–37.—TELEPHONE, CABLE TESTING, CIRCUITS.

DUTIES OF TESTER.

The galvanometer should be set up on solid foundation in such relation to the strongest light that the scale is most illuminated while the mirror is in the shadow. The box containing the insulation and capacity-testing set should be placed on a dry foundation. The 100,000 ohm box should be wired permanently into circuit, to avoid dangerous currents, and should also be placed on a dry foundation.

Ordinarily it is advisable to thoroughly insulate the battery. This may be accomplished by placing a piece of heated glass between battery and support or by suspending the battery from ceiling by means of a wire or cord, with a number of porcelain knobs connected in each hanger in such a manner that the cord or wire is not in one continuous piece. A torch may be applied occasionally to these porcelain knobs in order to disperse the slightest film of moisture that may collect.

While the tester is setting up the instruments, his assistant should get the cable ready for test. The assistant at the distant end of the cable should have been instructed to clear the ends of all conductors, scraping them carefully and taking care to keep them dry and clear of each other and ground, while the test of insulation and electrostatic capacity is in progress. In some instances it is necessary to apply the flame of a small alcohol torch to the ends of the conductors in order to dissipate all moisture. If this is resorted to, great care should be taken to avoid overheating the insulation, as it will result in showing comparatively heavy leakage. A gasoline flame, or any flame which will smoke the ends of conductors, should not be used.

The testing telephone may be used in connection with identification of conductors on long cables, especially those having rubber insulation or whenever communication between tester and his assistant at opposite end of the cable is desired.

In testing short subterranean cables a satisfactory substitute for this telephone for the purpose mentioned above is two Coast Artillery type head sets, one of these head sets to be used at each end of the cable. To use these head sets as a telephone, tie back out of the way the common wire (black) of each head set, as this wire is not used. Connect either of the two remaining wires (red and yellow) of one of the head sets to cable sheath in series with two cells of dry batteries, the other wire to be attached to conductor over which it is desired to communicate. The other head set at opposite end of cable is connected similarly, except that the cells of dry battery are omitted.

Identification of conductors can very quickly be made by this means, as it is only necessary for tester to connect one wire of his head set to a conductor of cable and assistant at other end to slide one wire of his head set over conductors. When the conductor selected by tester is touched, the assistant receives a loud click in the receiver of his head set. He immediately touches the wire again and responds with "Hello" in the mouthpiece of the transmitter. The tester assigns a number to the conductor used. Immediately following this procedure the tester disconnects wire of head set from cable conductor and connects it to another conductor. The operation is repeated until numbers have been assigned all conductors of the cable being tested.

A check test should then be made. This can be very quickly accomplished, as it should not be necessary to hunt for conductors.

Having identified all conductors, the tester instructs the distant assistant to see that all wires are clear, except one used for the telephone, and then to report. When all are reported clear, the assistant may be instructed to stand by and await orders; under no conditions to touch the cleared wires unless told to do so.

INSULATION MEASUREMENTS.

THE AUTHOR'S EXPLANATION OF PRINCIPLE INVOLVED IN MAKING INSULATION RESISTANCE MEASUREMENTS.

The method employed is a comparison of insulation resistance value of cable with a known resistance. In order to make this comparison it is necessary to know the number of divisions deflection on galvanometer scale that will be obtained when a current of uniform strength is caused to flow through the known resistance and the galvanometer coil in series. It must be remembered that the deflection of galvanometer armature is dependent upon the strength of current that is flowing through its coil or winding and that strength of direct current in any circuit is dependent on E. M. F. and resistance of circuit.

When the number of divisions deflection through a known resistance is known, it is merely necessary to compare the divisions deflection obtained through an unknown resistance with the former to determine value of unknown resistance. Example: If a scale deflection of 10 divisions is obtained through 1 ohm and a deflection of 2 divisions is obtained through insulation of cable, what is insulation resistance of cable? Ten divisions divided by 2 divisions equals 5, therefore only one-fifth as many divisions deflection is obtained through the insulation of the cable as that obtained through 1 ohm, consequently the insulation resistance of cable must be five times 1 ohm, or 5 ohms. Now, assume this cable to be 2 miles long and it is desired to determine the insulation per mile of such a cable. If sufficient current can escape through 2 miles of the insulation to establish a value of 5 ohms insulation resistance, 1 mile of such insulation would allow only sufficient current through it to show two times as high a resistance, or 5 ohms$\times$2=10 ohms, the insulation resistance of such cable per mile.

While the foregoing clearly demonstrates the principle involved in computing insulation measurements, the values usually encountered are very much higher. For instance, the Signal Corps specifications require certain cable to have an insulation resistance of at least 1,400 megohms per mile. One megohm equals 1,000,000 ohms. The reader can readily understand that in measuring such values it will be advantageous to know the divisions deflection through a much higher resistance than 1 ohm, consequently the standard used is 100,000 ohms, or $\frac{1}{10}$ megohm. In measuring high insulation values a battery of high voltage must be used, as with exceedingly high insulation resistance a deflection of one division on the galvanometer scale will not be obtained unless high E. M. F. is used, for it must be remembered that divisions deflection is dependent upon current strength, and, according to Ohm's law, current strength equals electromotive force divided by resistance in ohms.

Assume that a deflection of 10 scale divisions was obtained in measuring the insulation of a cable, that the insulation value was 1,000 megohms, and that the known resistance was $\frac{1}{10}$ megohm; referring to the first example quoted in the foregoing and working backward, we will find that the divisions deflection obtained when the known resistance was measured was 100,000 divisions.

It is impracticable to construct galvanometers with such a range, consequently an instrument termed a shunt is used, and by its means only a known fraction of the current in the circuit is passed through the galvanometer. These shunts are usually made so the fraction can be changed at will and any one of the following fractions of current passed through galvanometer, $\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1000}$, $\frac{1}{10000}$. As previously stated, the divisions deflection are directly proportional to current strength, therefore if 10 divisions are obtained when $\frac{1}{10}$ shunt is used the true deflection is ten times as great, or 100.

Let us now refer to the last example and assume that in measuring through the known resistance ($\frac{1}{10}$ megohm) the $\frac{1}{1000}$ shunt was used. If the true deflection was 100,000 divisions the deflection obtained using the $\frac{1}{1000}$ shunt was one one-thousandth of the true deflection or 100,000 divided by 1,000 equals 100 divisions (a fair scale reading).

In observing the reading on known resistance, where the lowest fractional proportion of the shunt will not restrict the reading to the scale of the galvanometer when using the battery to be employed in taking the reading on insulation of cable, it is necessary to reduce the voltage of the battery and again increase it when reading is made on insulation of cable.

Again referring to Ohm's law $I=\frac{E}{R}$ therefore the current flow is also directly proportional to the voltage impressed on the circuit. If a voltage of 10 volts is used in obtaining deflection with known resistance and 100 volts is used in obtaining deflection with insulation of cable, the true deflection on the known resistance will be ten times the one obtained, as the voltage of the latter is ten times as great. Thus it will be seen that in measuring high insulation resistance the divisions deflection through insulation are observed with full value of battery and with galvanometer unshunted so that full strength of current flows through galvanometer armature winding; it will also be observed that in obtaining divisions deflection through a known resistance the galvanometer is shunted or battery voltage reduced, or both, and that therefore it is necessary to compute in order to obtain the true deflection that would obtain were conditions similar to those when deflection through insulation resistance is observed.

The operation of finding the scale divisions deflection through a known resistance is termed "Determining the galvanometer constant." This constant is expressed in the number of megohms that would be in the circuit when a true deflection of one scale division is obtained or number of true scale divisions deflection that would be obtained in measuring through 1 megohm resistance.

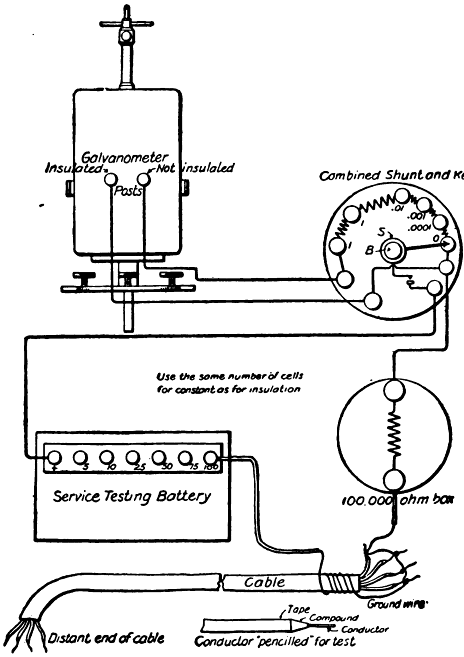

Fig. 4–38.—CABLE TESTING, GALVANOMETER CONSTANT.

The sensibility of a galvanometer is expressed in meghoms. It is the number of megohms required in the circuit to give a reading of one scale division using a battery voltage of 1 volt. Example: Using battery of 100 V, $\frac{1}{10000}$ shunt and $\frac{1}{10}$ megohm as known resistance, a deflection of 30 divisions is obtained, what is sensibility of galvanometer?

(d) = Divisions deflection.
(s) = Multiplying power of shunt.
(v) = Voltage.
(kr) = Known resistance in megohms.

$\frac{1}{v} \times s \times kr \times d$ = megohms sensibility (or divisions deflection through 1 megohm) substituting the above values:

$\frac{1}{100} \times 10000 \times \frac{1}{10} \times 30 = 300$ divisions through 1 megohm at 1 volt. This is equivalent to 1 division through 300 megohms at 1 volt. Therefore the sensibility of galvanometer is 300 megohms.

CORRECTION FOR LEADS.

On preparing for readings of insulation, capacity, and copper resistance, readings should be taken for each of these values on the leads and recorded for correction of the respective test readings.

TO DETERMINE THE GALVANOMETER CONSTANT.

The tester proceeds to get his galvanometer constant for insulation, as follows:

With connections as shown in figure 4–38, he moves the shunt to 0.0001 and depresses the battery key on shunt. The constant is then determined by dividing the resulting deflection by the shunt value and then dividing by 10, the standard resistance box being only 100,000 ohms instead of 1 megohm. This gives the deflection which the battery used would cause through 1 megohm without shunt.

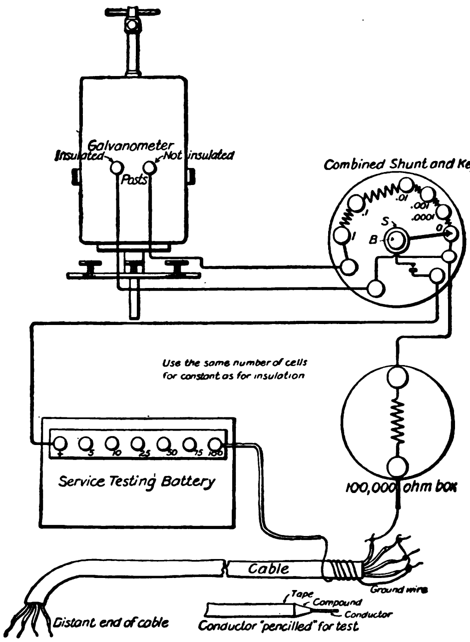

Fig. 4–39.—CABLE TESTING, INSULATION.

It is most important to use the same battery voltage in testing as in determining the constant, or make due allowance for change of voltage in computing test results. For insulation tests it is customary to utilize a voltage of approximately 100.

INSULATION TEST.

Connections are then made as shown in figure 4–39. This connection puts the galvanometer and battery in series, through the shunt and 100,000-ohm box, with the conductor, its insulation throughout its whole length and ground. All the other conductors of the cable should also be connected to ground. The test is therefore against all the other conductors and ground, thus determining the existence of crosses between conductors as well as insulation to ground.

Having connected thus to No. 1 conductor, the shunt is set at 0.0001 and the battery button depressed. With rubber cables an electrification of one minute is desirable. In paper cable the electrification is practically instantaneous, and the shunt may be moved to gradually smaller values until a readable deflection is obtained. The deflection, shunt, and conductor number are then entered in a notebook, and if the reading is normal the conductor is replaced in the bunch and the next one is tested.

On comparatively short cables where exact readings are impracticable 30 seconds' electrification is sufficient.

Should trouble be found, the assistant should be called and asked to scrape the insulation of the conductor in question carefully and see that it is free. Having identified all wires, it is a simple matter to test the telephone wire by substituting for the telephone line one of the wires first tested.

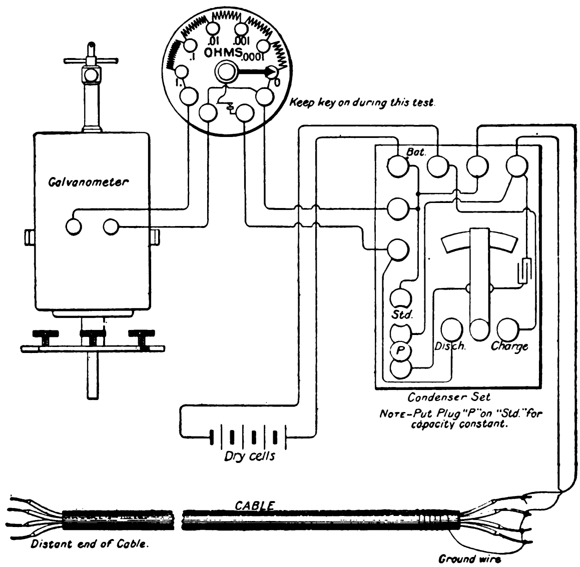

Fig. 4-40.—CABLE TESTING, CAPACITY.

The following example is submitted to indicate the method of calculating the insulation resistance of a cable.

Suppose our deflection through 100,000 ohms, using 0.0001 shunt, to be 80 divisions, then the constant equals 80 divided by 0.0001 and multiplied by one-tenth. Constant equals 80,000.

Suppose our deflection on conductor No. 1 is 40, with a shunt value of 1; then, since the constant is the deflection through 1 megohm, the number of megohms represented by this deflection will be 80,000 divided by 40, or 2,000 megohms.

If the cable were 1½ miles long, to reduce this value to megohms per mile it would be necessary to multiply it by 1½, and the insulation resistance per mile would be 3,000 megohms, an average value for paper-insulation cables not including pot heads under usual weather conditions.

The conductors of all completed cables of systems using new cable should show an insulation resistance of at least 500 megohms per mile. The conductors of all completed cables of systems using recovered cable should show an insulation resistance of at least 300 megohms per mile.

CAPACITY TEST.

Having obtained the insulation resistance of all the conductors, the battery is disconnected, the 100,000-ohm box is set aside, and the condenser set is connected as shown in figure 4–40. The condenser set is held in the hand or may be placed on table. If the latter is resorted to, the condenser should be placed between cleats fastened to table in order that switch of set may be positively and quickly operated. Suitable battery (not more than 5 or 10 cells) is connected to the condenser. The deflection on the standard condenser is then compared with the deflection caused by the cable, using the same battery and shunt value.

The following example shows the method of calculating capacity:

Suppose the deflection through the standard condenser were 150 and the leads were negligible.

Suppose our deflection through the cable were 450.

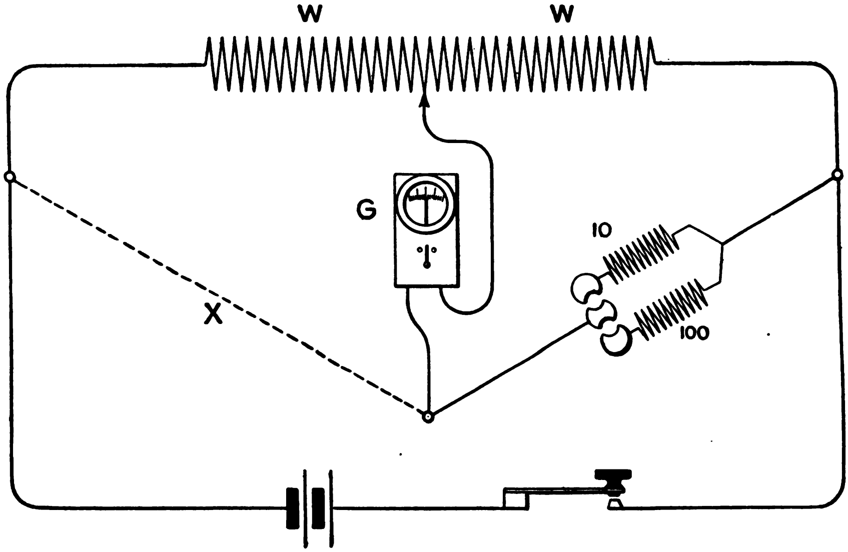

Fig. 4–41.—OHMMETER, THEORY.

The capacity of the cable would then be 450 divided by 150, or 3 times the capacity of standard (one-third M. F.). The cable capacity therefore would be 1 microfarad.

If the cable were 2 miles long, its capacity per mile would be 1 divided by 2, or 0.5 microfarads, a little above the average for rubber cable.

OHMMETER, MODEL 1904.

The theoretical diagram of the ohmmeter, model 1904, is given in figure 4–41, in which the parts of the conventional form of the Wheatstone bridge are apparent. The *A* and *B*, or "balance arms," are the two parts of the bridge wire *W W* into which it is divided by the "toucher."

The two standard resistance coils 10 and 100 ohms, respectively, correspond to the *R* arm of the bridge, *X* (the unknown resistance) forming the other arm. The telephone receiver may take the place of the galvanometer, balance being indicated by the cessation of the clicks and frying sound when the toucher has reached the proper graduation on the bridge wire.

DIRECTIONS FOR USING THE OHMMETER, MODEL 1904.

Connect a battery, preferably a couple of dry cells external to the testing set, to posts marked "Bat." and the unknown resistance to posts X_1, X_2. If the

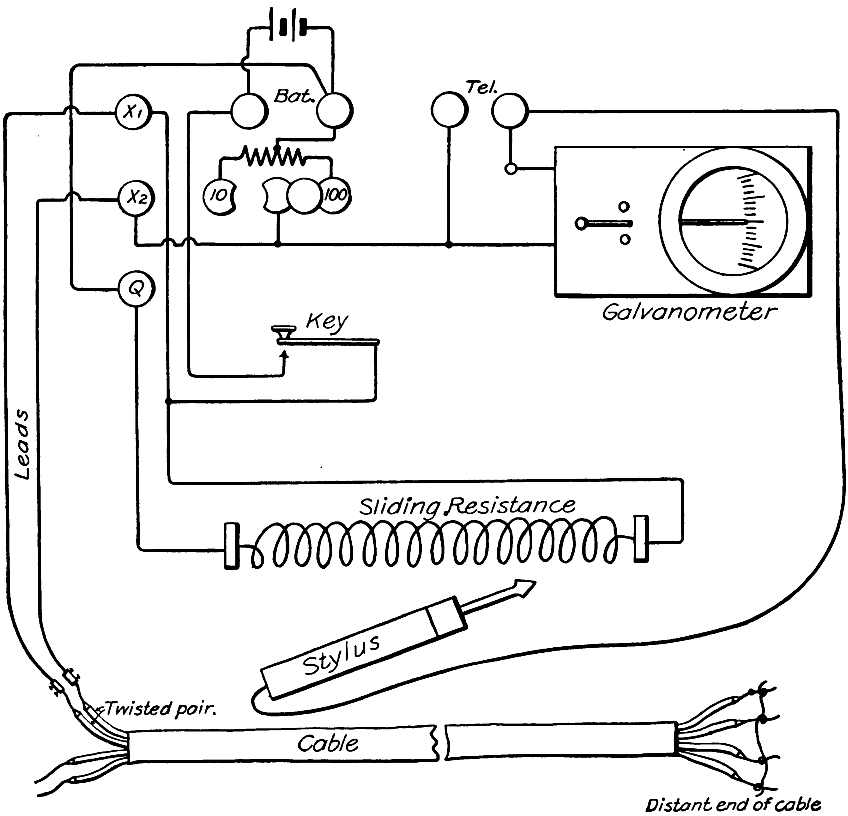

Fig. 4–42.—OHMMETER, RESISTANCE MEASUREMENT.

resistance is small, insert the plug at 10 and if large at 100. Depress the key and operate catch; then draw the stylus *lightly* across the horizontal scale, touching the convolutions of wire until the galvanometer reverses its deflection.

Multiples of 50 are read on the horizontal scale and fractions of a turn on the drum at the right. The tabular number corresponding to this number, as found in the table on the lid of the ohmmeter, when multiplied by 10 or 100, depending on whether the plug is at 10 or 100, will give the correct resistance.

For example, if the balance is found between convolutions Nos. 150 and 200 on the horizontal scale and the drum scale reads 46, the exact reading is 196. Referring to the table, the number corresponding to this is 0.2438, and the resistance, if the plug is inserted at 10, will be 2.438 ohms; or, if the plug is inserted at 100, will be 24.38 ohms.

A telephone receiver may be used in place of the galvanometer in the ohmmeter by disconnecting one of the cords from the post marked "*Tel.*" and connecting the receiver to those posts.

The portable galvanometer may be used in the place of the galvanometer in the ohmmeter by proceeding as for the receiver. In this case it would be advisable, however, to make use of the galvanometer with shunt.

The method of measuring conductor resistance of a cable is shown in figure 4–42. The copper resistance is tested in pairs and should not vary to any great extent (in very large cables the outer layers will be a few per cent higher in resistance than the inner layers). The resistance per stretch is ordinarily determined by dividing the loop reading by 2. The resistance per mile is determined by dividing the total resistance per stretch by the number of miles in the stretch.

Methods of testing to locate faults in cables are described in detail, chapter 9.

POINTS FOR THE TESTER.

1. Never open a paper cable on a damp, misty, or rainy day, whether under cover or not.
2. Never pronounce a cable bad until you are satisfied that all ends are absolutely clear and dry.
3. Never test any kind of cable on a damp day if it can be avoided.
4. Use the service-testing battery for insulation only, thus saving it against possible short circuit or heavy drain.
5. Get thoroughly acquainted with the instruments before starting the test and mark all the adjustments, so that little time need be wasted in setting up.
6. Remember that accurate readings never are possible under moist conditions, and instruments and leads should be as dry as practicable.
7. The micrometer caliper should be used to determine exact diameter of the conductor.
8. All data concerning the cable should be recorded before taking down the instruments, being sure that data is complete for each conductor.

The following tables contain data which may be of value to the tester:

Table of dimensions, weight, and length of pure copper wire.

Size, Brown & Sharpe.	Diameter, mils.	Circular, mils. (d^2). 1 mil.=.001 in.	Pounds per 1,000 feet.	Pounds per mile.	Feet per pound.
0000	460.000	211600.00	639.33	3,375.7	1.56
000	409.640	167805.00	507.01	2,677.0	1.97
00	364.800	133079.40	402.09	2,123.0	2.49
0	324.860	105538.00	318.86	1,683.6	3.14
1	289.300	83694.20	252.88	1,335.2	3.95
2	257.630	66373.00	200.54	1,058.8	4.99
3	229.420	52634.00	159.03	839.68	6.29
4	204.310	41742.00	126.12	665.91	7.93
5	181.940	33102.00	100.01	528.05	10.00
6	162.020	26250.50	79.32	418.81	12.61
7	144.280	20816.00	62.90	332.11	15.90
8	128.490	16509.00	49.88	263.37	20.05
9	114.430	13094.00	39.56	208.88	25.28
10	101.890	10381.00	31.37	165.63	31.38
11	90.742	8234.00	24.88	131.37	40.20
12	80.808	6529.90	19.73	104.18	50.69
13	71.961	5178.40	15.65	82.632	63.91
14	64.048	4106.70	12.44	65.674	80.38
15	57.068	3256.7	9.84	51.956	101.63
16	50.820	2582.9	7.81	41.237	128.14
17	45.257	2048.2	6.19	32.683	161.59
18	40.303	1624.3	4.91	25.925	203.76
19	35.876	1287.1	3.88	20.507	257.47
20	31.961	1021.5	3.09	16.315	324.00
21	28.462	810.10	2.45	12.936	408.56
22	25.347	642.70	1.94	10.243	515.15
23	22.571	509.45	1.54	8.1312	649.66
24	20.100	404.01	1.22	6.4416	819.21
25	17.900	320.40	.97	5.1216	1,032.96
26	15.940	254.01	.77	4.0656	1,302.61
27	14.195	201.50	.61	3.2208	1,642.55
28	12.641	159.79	.48	2.5344	2,071.22
29	11.257	126.72	.38	2.0064	2,611.82
30	10.025	100.5	.30	1.5840	3,293.97
31	8.928	79.71	.24	1.2672	4,152.22
32	7.950	63.20	.19	1.0032	5,236.66
33	7.080	50.13	.15	.7920	6,602.71
34	6.304	39.74	.12	.6336	8,328.30
35	5.614	31.52	.10	.5280	10,501.35
36	5.000	25.00	.08	.4224	13,238.83
37	4.453	19.83	.06	.3168	16,691.06
38	3.965	15.72	.05	.2640	20,854.65
39	3.531	12.47	.04	.2112	26,302.23
40	3.144	9.89	.03	.1584	33,175.94

Table of resistances of pure copper wire at 75° F.

Size, Brown & Sharpe.	Ohms per 1,000 feet.	Ohms per mile.	Ohms per pound.	Feet per ohm.
0000	0.04906	0.25903	0.000076736	20,383.0
000	.06186	.32664	.00012039	16,165.0
00	.07801	.41187	.00019423	12,820.0
0	.09838	.51937	.00038500	10,166.0
1	.12404	.65490	.00048994	8,062.3
2	.15640	.82582	.00078045	6,393.7
3	.19723	1.0414	.0012406	5,070.2
4	.24869	1.3131	.0019721	4,021.0
5	.31361	1.6558	.0031361	3,188.7
6	.39546	2.0881	.0049868	2,528.7
7	.49871	2.6331	.0079294	2,005.2
8	.62881	3.3201	.012608	1,590.3
9	.79281	4.1860	.020042	1,261.3
10	1.0000	5.2800	.031380	1,000.0
11	1.2607	6.6568	.050682	793.18
12	1.5898	8.3940	.080585	629.02
13	2.0047	10.585	.12841	498.83
14	2.5278	13.347	.20322	395.60
15	3.1150	16.477	.31658	321.02
16	4.0191	21.221	.51501	248.81
17	5.0683	26.761	.81900	197.30
18	6.3911	33.745	1.3023	156.47
19	8.0654	42.585	2.0759	123.99
20	10.163	53.658	3.2926	98.401
21	12.815	67.660	5.2355	78.067
22	16.152	85.283	8.3208	61.911
23	20.377	107.59	13.238	49.087
24	25.695	135.67	21.050	38.918
25	32.400	171.07	33.466	30.864
26	40.868	215.79	35.235	24.469
27	51.519	272.02	84.644	19.410
28	64.966	343.02	134.56	15.393
29	81.921	432.54	213.96	12.207
30	103.30	545.39	340.25	9.6812
31	127.27	671.99	528.45	7.8573
32	164.26	867.27	860.33	6.0880
33	207.08	1,093.4	1,367.3	4.8290
34	261.23	1,379.3	2,175.5	3.8281
35	329.35	1,738.9	3,458.5	3.0363
36	415.24	2,192.5	5,497.4	2.4082
37	523.76	2,765.5	8,742.1	1.9093
38	660.37	3,486.7	13,772.	1.5143
39	832.48	4,395.5	21,896.	1.2012
40	1,049.7	5,542.1	34,823.	.9527

In reducing the insulation resistance of Okonite, Habirshaw, or Bishop compounds to 60° F., the total difference between the temperature of observation and the standard temperature, 60°, will be determined and the proper coefficient will be found by referring to the table. For example, if the temperature were 75°, the difference of temperature, 15°, would call for a coefficient of 1.470, by which the insulation resistance, as calculated, will be multiplied to determine the correct value at 60° F.

Temperature of coefficients for the reduction of insulation resistance to 60° F.

OKONITE, HABIRSHAW, AND BISHOP COMPOUNDS.

Difference of temperature.	Coefficient.	Difference of temperature.	Coefficient.	Difference of temperature.	Coefficient.
° F.		*° F.*		*° F.*	
1	1.026	18	1.587	35	2.456
2	1.053	19	1.629	36	2.520
3	1.080	20	1.671	37	2.586
4	1.108	21	1.715	38	2.653
5	1.137	22	1.759	39	2.722
6	1.167	23	1.805	40	2.796
7	1.197	24	1.852	41	2.865
8	1.228	25	1.900	42	2.940
9	1.260	26	1.949	43	3.016
10	1.293	27	2.000	44	3.091
11	1.326	28	2.052	45	3.175
12	1.361	29	2.105	46	3.258
13	1.396	30	2.160	47	3.342
14	1.433	31	2.216	48	3.429
15	1.470	32	2.274	49	3.518
16	1.508	33	2.333	50	3.610
17	1.547	34	2.394		

To correct insulation resistance for temperature where the cables are made up of Safety, Kerite, or Standard underground rubber compounds, reference should be made to one of the following tables for the temperature coefficient at the observed temperature. The correct resistance is obtained by multiplying the calculated resistance by the coefficient found in the table for that compound opposite the observed temperature.

SAFETY COMPOUND.

Temperature.	Coefficient.	Temperature.	Coefficient.	Temperature.	Coefficient.
° F.		*° F.*		*° F.*	
20	0.4399	47	0.7386	74	1.4407
21	.4472	48	.7551	75	1.4811
22	.4547	49	.7721	76	1.5228
23	.4625	50	.7897	77	1.5647
24	.4705	51	.8078	78	1.6110
25	.4787	52	.8265	79	1.6728
26	.4869	53	.8458	80	1.7056
27	.4959	54	.8658	81	1.7556
28	.5049	55	.8864	82	1.8073
29	.5141	56	.9076	83	1.8610
30	.5237	57	.9296	84	1.9167
31	.5335	58	.9523	85	1.9744
32	.5437	59	.9758	86	2.0343
33	.5542	60	1.0000	87	2.0964
34	.5648	61	1.0251	88	2.1609
35	.5759	62	1.0510	89	2.2278
36	.5873	63	1.0777	90	2.2973
37	.5990	64	1.1054	91	2.3694
38	.6112	65	1.1340	92	2.4443
39	.6236	66	1.1636	93	2.5223
40	.6351	67	1.1943	94	2.6028
41	.6498	68	1.2260	95	2.6868
42	.6635	69	1.2587	96	2.7740
43	.6776	70	1.2927	97	2.8646
44	.6921	71	1.3278	98	2.9587
45	.7071	72	1.3641	99	3.0566
46	.7226	73	1.4017	100	3.1584

Temperature of coefficients for the reduction of insulation resistance to 60° F.—Continued.

KERITE COMPOUND.

Temperature.	Coefficient.	Temperature.	Coefficient.	Temperature.	Coefficient.
° *F.*		° *F.*		° *F.*	
20	0.2706	47	0.5187	74	2.6023
21	.2725	48	.5413	75	2.8410
22	.2747	49	.5655	76	3.0469
23	.2774	50	.5917	77	3.3035
24	.2804	51	.6199	78	3.5865
25	.2839	52	.6503	79	3.8988
26	.2877	53	.6831	80	4.2438
27	.2921	54	.7184	81	4.6256
28	.2968	55	.7566	82	5.0483
29	.3020	56	.7979	83	5.5169
30	.3078	57	.8426	84	6.0371
31	.3141	58	.8909	85	6.6149
32	.3209	59	.9433	86	7.2577
33	.3283	60	1.0000	87	7.9734
34	.3363	61	1.0616	88	8.7713
35	.3449	62	1.1281	89	9.6617
36	.3543	63	1.2010	90	10.6566
37	.3644	64	1.2800	91	11.7695
38	.3752	65	1.3660	92	13.0158
39	.3869	66	1.4597	93	14.4130
40	.3995	67	1.5618	94	15.9814
41	.4131	68	1.6772	95	17.7438
42	.4276	69	1.7952	96	19.7265
43	.4433	70	1.9285	97	21.9598
44	.4601	71	2.0744	98	24.4782
45	.4782	72	2.2343	99	27.3215
46	.4977	73	2.4097	100	30.5353

STANDARD UNDERGROUND CO.'S RUBBER "D."

Temperature.	Coefficient.	Temperature.	Coefficient.	Temperature.	Coefficient.
° *F.*		° *F.*		° *F.*	
20	0.5536	47	0.8051	74	1.2970
21	.5603	48	.8179	75	1.3227
22	.5672	49	.8311	76	1.3491
23	.5742	50	.8446	77	1.3762
24	.5814	51	.8584	78	1.4041
25	.5888	52	.8726	79	1.4328
26	.5964	53	.8872	80	1.4622
27	.6041	54	.9021	81	1.4924
28	.6120	55	.9174	82	1.5235
29	.6201	56	.9331	83	1.5554
30	.6284	57	.9492	84	1.5883
31	.6369	58	.9657	85	1.6220
32	.6456	59	.9826	86	1.6568
33	.6546	60	1.0000	87	1.6924
34	.6626	61	1.0178	88	1.7291
35	.6731	62	1.0361	89	1.7669
36	.6827	63	1.0549	90	1.8057
37	.6925	64	1.0741	91	1.8457
38	.7026	65	1.0939	92	1.8867
39	.7129	66	1.1141	93	1.9290
40	.7234	67	1.1349	94	1.9725
41	.7343	68	1.1563	95	2.0173
42	.7454	69	1.1782	96	2.0633
43	.7567	70	1.2007	97	2.1107
44	.7684	71	1.2239	98	2.1595
45	.7803	72	1.2476	99	2.2098
46	.7925	73	1.2720	100	2.2615

The resistance of copper increases with the increase of temperature. In order to reduce copper resistances at any temperature between 0° and 120° F. to 60° F., the following table has been calculated, in which δ is the factor by which the resistance at the observed temperature should be multiplied to reduce it to 60° F.:

Reduction of copper resistance to 60° F.

Temperature.	δ	Temperature.	δ	Temperature.	δ
° *F.*		° *F.*		° *F.*	
0	1.1538	41	1.0443	82	0.9529
1	1.1509	42	1.0419	83	.9508
2	1.1480	43	1.0395	84	.9488
3	1.1451	44	1.0371	85	.9468
4	1.1422	45	1.0347	86	.9448
5	1.1393	46	1.0323	87	.9428
6	1.1364	47	1.0300	88	.9408
7	1.1336	48	1.0276	89	.9388
8	1.1308	49	1.0252	90	.9368
9	1.1280	50	1.0229	91	.9348
10	1.1252	51	1.0206	92	.9328
11	1.1224	52	1.0182	93	.9308
12	1.1196	53	1.0159	94	.9288
13	1.1168	54	1.0136	95	.9269
14	1.1141	55	1.0113	96	.9250
15	1.1113	56	1.0090	97	.9231
16	1.1086	57	1.0068	98	.9211
17	1.1059	58	1.0045	99	.9192
18	1.1032	59	1.0023	100	.9173
19	1.1005	60	1.0000	101	.9154
20	1.0978	61	.9978	102	.9135
21	1.0952	62	.9956	103	.9116
22	1.0925	63	.9933	104	.9097
23	1.0899	64	.9911	105	.9097
24	1.0873	65	.9889	106	.9060
25	1.0846	66	.9867	107	.9041
26	1.0820	67	.9846	108	.9022
27	1.0794	68	.9824	109	.9004
28	1.0769	69	.9802	110	.8986
29	1.0743	70	.9781	111	.8968
30	1.0717	71	.9759	112	.8949
31	1.0692	72	.9738	113	.8931
32	1.0667	73	.9717	114	.8913
33	1.0641	74	.9695	115	.8895
34	1.0616	75	.9674	116	.8877
35	1.0591	76	.9653	117	.8859
36	1.0566	77	.9632	118	.8841
37	1.0542	78	.9611	119	.8824
38	1.0517	79	.9591	120	.8806
39	1.0492	80	.9570		
40	1.0468	81	.9549		

A general formula for reducing copper resistance at any observed temperature (T) to 60° F. is given by the following:

$$\delta = \frac{1.063}{1 + .00225\,(T - 32)}$$

Wire table, standard annealed copper.

[American wire gauge (B. & S.).]

Gauge No.	Diameter in mils.	Cross section.		Ohms per 1,000 feet.		
		Circular mils.	Square inches.	0° C. (=32° F.).	15° C. (=59° F.).	20° C. (=68° F.).
0000	460.0	211 600.	0.1662	0.045 14	0.048 04	0.049 01
000	409.6	167 800.	.1318	.056 93	.060 58	.061 80
00	364.8	133 100.	.1045	.071 78	.076 39	.077 93
0	324.9	105 500.	.082 89	.090 52	.096 33	.098 27
1	289.3	83 690.	.065 73	.1141	.1215	.1239
2	257.6	66 370.	.052 13	.1439	.1532	.1563
3	229.4	52 640.	.041 34	.1815	.1931	.1970
4	204.3	41 740.	.032 78	.2288	.2436	.2485
5	181.9	33 100.	.026 00	.2886	.3071	.3133
6	162.0	26 250.	.020 62	.3639	.3872	.3951
7	144.3	20 820.	.016 35	.4589	.4883	.4982
8	128.5	16 510.	.012 97	.5786	.6158	.6282
9	114.4	13 090.	.010 28	.7296	.7765	.7921
10	101.9	10 380.	.008 155	.9200	.9792	.9989
11	90.74	8234.	.006 467	1.160	1.235	1.260
12	80.81	6530.	.005 129	1.463	1.557	1.588
13	71.96	5178.	.004 067	1.845	1.963	2.003
14	64.08	4107.	.003 225	2.326	2.475	2.525
15	57.07	3257.	.002 558	2.933	3.121	3.184
16	50.82	2583.	.002 028	3.699	3.936	4.015
17	45.26	2048.	.001 609	4.664	4.963	5.064
18	40.30	1624.	.001 276	5.881	6.259	6.385
19	35.89	1288.	.001 012	7.416	7.892	8.051
20	31.96	1022.	.000 802 3	9.352	9.953	10.15
21	28.46	810.1	.000 636 3	11.79	12.55	12.80
22	25.35	642.4	.000 504 6	14.87	15.82	16.14
23	22.57	509.5	.000 400 2	18.75	19.95	20.36
24	20.10	404.0	.000 317 3	23.64	25.16	25.67
25	17.90	320.4	.000 251 7	29.81	31.73	32.37
26	15.94	254.1	.000 199 6	37.59	40.01	40.82
27	14.20	201.5	.000 158 3	47.40	50.45	51.46
28	12.64	159.8	.000 125 5	59.77	63.61	64.90
29	11.26	126.7	.000 099 53	75.37	80.22	81.84
30	10.03	100.5	.000 078 94	95.05	101.2	103.2
31	8.928	79.70	.000 062 60	119.8	127.6	130.1
32	7.950	63.21	.000 049 64	151.1	160.8	164.1
33	7.080	50.13	.000 039 37	190.6	202.8	206.9
34	6.305	39.75	.000 031 22	240.3	255.7	260.9
35	5.615	31.52	.000 024 76	303.0	322.5	329.0
36	5.000	25.00	.000 019 64	382.1	406.6	414.8
37	4.453	19.83	.000 015 57	481.8	512.8	523.1
38	3.965	15.72	.000 012 35	607.5	646.6	659.6
39	3.531	12.47	.000 009 793	766.1	815.4	831.8
40	3.145	9.888	.000 007 766	966.1	1028.	1049.

Wire table, standard annealed copper—Continued.

[American wire gauge (B. & S.).]

Gauge No.	Diameter in mils.	Cross section.		Ohms per 1,000 feet.		
		Circular mils.	Square inches.	25° C. (=77° F.).	50° C. (=122° F.).	75° C. (=167° F.).
0000	460.0	211 600.	0.1662	0.049 98	0.054 82	0.059 65
000	409.6	167 800.	.1318	.063 03	.069 12	.075 22
00	364.8	133 100.	.1045	.079 47	.087 16	.094 85
0	324.9	105 500.	.082 89	.1002	.1099	.1196
1	289.3	83 690.	.065 73	.1264	.1386	.1508
2	257.6	66 370.	.052 13	.1594	.1748	.1902
3	229.4	52 640.	.041 34	.2009	.2204	.2398
4	204.3	41 740.	.032.78	.2534	.2779	.3024
5	181.9	33 100.	.026 00	.3195	.3504	.3813
6	162.0	26 250.	.020 62	.4029	.4418	.4808
7	144.3	20 820.	.016 35	.5080	.5572	.6064
8	128.5	16 510.	.012 97	.6406	.7025	.7645
9	114.4	13 090.	.010 28	.8078	.8860	.9641
10	101.9	10 380.	.008 155	1.019	1.117	1.216
11	90.74	8234.	.006 467	1.284	1.409	1.533
12	80.81	6530.	.005 129	1.620	1.776	1.933
13	71.96	5178.	.004 067	2.042	2.240	2.438
14	64.08	4107.	.003 225	2.576	2.824	3.074
15	57.07	3257.	.002 558	3.248	3.562	3.876
16	50.82	2583.	.002 028	4.095	4.491	4.887
17	45.26	2048.	.001 609	5.164	5.663	6.162
18	40.30	1624.	.001 276	6.512	7.141	7.771
19	35.89	1288.	.001 012	8.210	9.004	9.799
20	31.96	1022.	.000 802 3	10.35	11.36	12.36
21	28.46	810.1	.000 636 3	13.06	14.32	15.58
22	25.35	642.4	.000 504 6	16.46	18.06	19.65
23	22.57	509.5	.000 400 2	20.76	22.77	24.78
24	20.10	404.0	.000 317 3	26.18	28.71	31.24
25	17.90	320.4	.000 251 7	33.01	36.20	39.39
26	15.94	254.1	.000 199 6	41.62	45.65	49.68
27	14.20	201.5	.000 158 3	52.48	57.56	62.64
28	12.64	159.8	.000 125 5	66.18	72.59	78.98
29	11.26	126.7	.000 099 53	83.46	91.53	99.60
30	10.03	100.5	.000 078 94	105.2	115.4	125.6
31	8.928	79.70	.000 062 60	132.7	145.5	158.4
32	7.950	63.21	.000 049 64	167.3	183.5	199.7
33	7.080	50.13	.000 039 37	211.0	231.4	251.8
34	6.305	39.75	.000 031 22	266.1	291.8	317.5
35	5.615	31.52	.000 024 76	335.5	367.9	400.4
36	5.000	25.00	.000 019 64	423.0	464.0	504.9
37	4.453	19.83	.000 015 57	533.5	585.1	636.7
38	3.965	15.72	.000 012 35	672.7	737.7	802.8
39	3.531	12.47	.000 009 793	848.2	930.2	1012.0
40	3.145	9.888	.000 007 766	1070.	1173.	1276.

Wire table, standard annealed copper.

[American wire gauge (B. & S.).]

Gauge No.	Diameter in mils.	Pounds per 1,000 feet.	Feet per pound.	Feet per ohm.					
				0° C. (=32° F.).	15° C. (=59° F.).	20° C. (=68° F.).	25° C. (=77° F.).	50° C. (=122° F.).	75° C. (=167° F.).
0000	460.0	640.5	1.561	22 150.	20 810.	20 400.	20 010.	18 240.	16 760.
000	409.6	507.9	1.968	17 570.	16 510.	16 180.	15 870.	14 470.	13 290.
00	364.8	402.8	2.482	13 930.	13 090.	12 830.	12 580.	11 470.	10 540.
0	324.9	319.5	3.130	11 050.	10 380.	10 180.	9979.	9098.	8361.
1	289.3	253.3	3.947	8751.	8233.	8070.	7913.	7215.	6630.
2	257.6	200.9	4.977	6948.	6529.	6400.	6276.	5722.	5258.
3	229.4	159.3	6.276	5510.	5178.	5075.	4977.	4538.	4170.
4	204.3	126.4	7.914	4370.	4106.	4025.	3947.	3599.	3307.
5	181.9	100.2	9.980	3465.	3256.	3192.	3130.	2854.	2622.
6	162.0	79.46	12.58	2748.	2582.	2531.	2482.	2263.	2080.
7	144.3	63.02	15.87	2179.	2048.	2007.	1968.	1795.	1649.
8	128.5	49.98	20.01	1728.	1624.	1592.	1561.	1423.	1308.
9	114.4	39.63	25.23	1371.	1288.	1262.	1238.	1129.	1037.
10	101.9	31.43	31.82	1087.	1021.	1001.	981.8	895.1	822.6
11	90.74	24.92	40.12	862.0	810.0	794.0	778.5	709.9	652.4
12	80.81	19.77	50.59	683.6	642.3	629.6	617.4	563.0	517.3
13	71.96	15.68	63.80	542.0	509.4	499.3	489.6	446.4	410.3
14	64.08	12.43	80.44	429.9	404.0	396.0	388.3	354.0	325.4
15	57.07	9.858	101.4	340.9	320.4	314.0	307.9	280.8	258.0
16	50.82	7.818	127.9	270.4	254.1	249.0	244.2	222.7	204.6
17	45.26	6.200	161.3	214.4	201.5	197.5	193.7	176.6	162.3
18	40.30	4.917	203.4	170.0	159.8	156.6	153.6	140.0	128.7
19	35.89	3.899	256.5	134.8	126.7	124.2	121.8	111.1	102.0
20	31.96	3.092	323.4	106.9	100.5	98.49	96.59	88.07	80.93
21	28.46	2.452	407.8	84.81	79.69	78.11	76.60	69.84	64.18
22	25.35	1.945	514.2	67.25	63.20	61.95	60.74	55.39	50.90
23	22.57	1.542	648.4	53.34	50.12	49.12	48.17	43.92	40.36
24	20.10	1.223	817.7	42.30	39.74	38.96	38.20	34.83	32.01
25	17.90	0.9699	1031.	33.54	31.52	30.90	30.30	27.62	25.39
26	15.94	.7692	1300.	26.60	25.00	24.50	24.02	21.91	20.13
27	14.20	.6100	1639.	21.10	19.82	19.43	19.05	17.37	15.96
28	12.64	.4837	2067.	16.73	15.72	15.41	15.11	13.78	12.66
29	11.26	.3836	2607.	13.27	12.47	12.22	11.98	10.93	10.04
30	10.03	.3042	3287.	10.52	9.886	9.691	9.503	8.665	7.962
31	8.928	.2413	4145.	8.344	7.840	7.685	7.536	6.871	6.314
32	7.950	.1913	5227.	6.617	6.218	6.094	5.976	5.449	5.008
33	7.080	.1517	6591.	5.247	4.931	4.833	4.739	4.322	3.971
34	6.305	.1203	8310.	4.161	3.910	3.833	3.759	3.427	3.149
35	5.615	.095 42	10 480.	3.300	3.101	3.040	2.981	2.718	2.497
36	5.000	.075 68	13 210.	2.617	2.459	2.410	2.364	2.155	1.981
37	4.453	.060 01	16 660.	2.075	1.950	1.912	1.874	1.709	1.571
38	3.965	.047 59	21 010.	1.646	1.547	1.516	1.487	1.356	1.246
39	3.531	.037 74	26 500.	1.305	1.226	1.202	1.179	1.075	0.9878
40	3.145	.029 93	33 410.	1.035	0.9727	0.9534	0.9349	0.8525	.7834

Wire table, standard annealed copper.

[American wire gauge (B. & S.).]

Gauge No.	Diameter in mils.	Ohms per pound.		
		0° C. (=32° F.).	15° C. (=59° F.).	20° C. (=68° F.).
0000	460.0	0.000 070 41	0.000 075 09	0.000 076 52
000	409.6	.000 1120	.000 1192	.000 1217
00	364.8	.000 1780	.000 1896	.000 1935
0	324.9	.000 2830	.000 3015	.000 3076
1	289.3	.000 4500	.000 4794	.000 4891
2	257.6	.000 7156	.000 7622	.000 7778
3	229.4	.001 138	.001 212	.001 237
4	204.3	.001 809	.001 927	.001 966
5	181.9	.002 877	.003 064	.003 127
6	162.0	.004 574	.004 872	.004 972
7	144.3	.007 273	.007 747	.007 906
8	128.5	.011 56	.012 32	.012 57
9	114.4	.018 39	.019 59	.019 99
10	101.9	.029 24	.031 15	.031 78
11	90.74	.046 49	.049 52	.050 53
12	80.81	.073 93	.078 74	.080 35
13	71.96	.1176	.1252	.1278
14	64.08	.1869	.1991	.2032
15	57.07	.2972	.3166	.3230
16	50.82	.4726	.5033	.5136
17	45.26	.7514	.8003	.8167
18	40.30	1.195	1.273	1.299
19	35.89	1.900	2.024	2.065
20	31.96	3.021	3.218	3.283
21	28.46	4.803	5.116	5.221
22	25.35	7.637	8.135	8.302
23	22.57	12.14	12.93	13.20
24	20.10	19.31	20.57	20.99
25	17.90	30.70	32.70	33.37
26	15.94	48.82	52.00	53.06
27	14.20	77.63	82.69	84.37
28	12.64	123.4	131.5	134.2
29	11.26	196.3	209.1	213.3
30	10.03	312.1	332.4	339.2
31	8.928	496.3	528.5	539.3
32	7.950	789.1	840.5	857.6
33	7.080	1255.	1336.	1364.
34	6.305	1995.	2125.	2168.
35	5.615	3172.	3379.	3448.
36	5.000	5044.	5372.	5482.
37	4.453	8020.	8542.	8717.
38	3.965	12 750.	13 580.	13 860.
39	3.531	20 280.	21 600.	22 040.
40	3.145	32 240.	34 340.	35 040.

Continued.

Wire table, standard annealed copper—Continued.

[American wire gauge (B. & S.).]

Gauge No.	Diameter in mils.	Ohms per pound.		
		25°C. (=77° F.).	50° C. (=122° F.).	75° C. (=167° F.).
0000	460.0	0.000 078 05	0.000 085 70	0.000 093 34
000	409.6	.000 1241	.000 1363	.000 1483
00	364.8	.000 1974	.000 2167	.000 2360
0	324.9	.000 3138	.000 3445	.000 3753
1	289.3	.000 4990	.000 5478	.000 5967
2	257.6	.000 7934	.000 8711	.000 9487
3	229.4	.001 262	.001 385	.001 508
4	204.3	.002 006	.002 202	.002 399
5	181.9	.003 189	.003 502	.003 813
6	162.0	.005 071	.005 568	.006 065
7	144.3	.008 064	.008 853	.009 643
8	128.5	.012 82	.014 08	.015 33
9	114.4	.020 39	.022 38	.024 38
10	101.9	.032 42	.035 59	.038 77
11	90.74	.051 55	.056 60	.061 64
12	80.81	.081 96	.089 99	.098 01
13	71.96	.1303	.1431	.1558
14	64.08	.2072	.2275	.2478
15	57.07	.3295	.3616	.3940
16	50.82	.5239	.5752	.6265
17	45.26	.8330	.9146	.9962
18	40.30	1.325	1.454	1.584
19	35.89	2.106	2.313	2.519
20	31.96	3.349	3.677	4.006
21	28.46	5.325	5.846	6.368
22	25.35	8.467	9.296	10.13
23	22.57	13.46	14.78	16.10
24	20.10	21.41	23.50	25.60
25	17.90	34.04	37.37	40.71
26	15.94	54.13	59.43	64.73
27	14.20	86.07	94.49	102.9
28	12.64	136.8	150.2	163.7
29	11.26	217.6	238.9	260.2
30	10.03	346.0	379.9	413.8
31	8.928	550.2	604.0	657.9
32	7.950	874.8	960.4	1046.
33	7.080	1391.	1527.	1663.
34	6.305	2212.	2428.	2645.
35	5.615	3517.	3861.	4205.
36	5.000	5592.	6139.	6687.
37	4.453	8892.	9762.	10 630.
38	3.965	14 140.	15 520.	16 900.
39	3.531	22 480.	24 680.	26 880.
40	3.145	35 740.	39 250.	42 750.

STANDARD CABLE CONSTANTS.

The standard subterranean rubber insulation cable has an insulation resistance of about 1,800 megohms per mile, a capacity of about 0.40 microfarad per mile, and a copper resistance of about 17 ohms per mile when laid. Average testing conditions should show indefinitely an insulation resistance of not less than 500 megohms per mile.

The standard rubber insulation submarine cable for fire-control and harbor work has an insulation resistance of about 2,000 megohms per mile, a capacity of about 0.48 microfarad per mile, and a copper resistance of about 17 ohms per mile when laid. Average testing conditions should show indefinitely an insulation resistance of not less than 600 megohms per mile.

The standard paper insulation cable for temporary and post connections having No. 19 B. & S. conductors has an insulation resistance of from 2,000 to 6,000 megohms per mile, a capacity of about 0.075 microfarad per mile, and a copper resistance of about 43 ohms per mile when in place. Average testing conditions should show indefinitely an insulation resistance of not less than 1,000 megohms per mile.

The paper insulation submarine cable has an insulation resistance as above and a capacity of 0.11, with copper resistance of 43 ohms per mile when laid. Average testing conditions should show indefinitely an insulation resistance of not less than 1,000 megohms.

All of the above figures are based on a temperature of 60° F.

ELECTROLYSIS.

Where a subterranean cable system is so located that there is a possibility of it being in the path of the return current of an electric railway, tests for the presence of electrolysis should be made. These tests should be made during "peak of load" at railway power house, if possible.

The tests consist of connecting cable sheath of various cables of the system at various points to a positive ground through a millivoltmeter. If practicable, the street railway track should be used for the ground connection.

If a reading (regardless of magnitude) is obtained with the millivoltmeter, the sheath of cable or cables should be permanently grounded at points where readings are obtained.

The usual custom is to bond the cables together and connect to one heavy conductor, which is connected solidly to the street railway track at a convenient point.

Condemned cable makes an excellent conductor for this purpose, the conductors and sheath both being used as the conducting medium.

FACTORY TESTING FOR THE ELECTRICAL PROPERTIES OF CABLE.

The Signal Corps specifications require the manufacturers to supply all instruments and facilities necessary for testing the cable. As these instruments are different at the different factories, a description of them will not be attempted. At the beginning of a series of tests at the factory, bridges, condensers, and high resistances must be compared with standards to verify their accuracy.

The high-voltage test is first applied to the core. The breakdown test for the standard core, after 24 hours' immersion in water, is the application of 6,500 volts alternating, for five minutes. This test will disclose any accidental impurities in the compound. While the specifications require the application of

6,500 volts for five minutes, if a breakdown occurs it will occur almost instantly after the application of the high voltage. One lead from the transformer is connected with the copper of the core and the other lead immersed in the water in the tank. For the finished cable 1,000 volts are applied between the armor and the core for one minute. When the high-voltage test is applied to lengths of armored cable of 50 miles or more, it is, perhaps, better to use direct rather than alternating voltage, to avoid any possibility of resonance and the formation of stationary waves.

After the application of the breakdown test, the capacity, insulation, and copper resistances of each length of the core are determined, in the order mentioned.

The capacity measurement is made by the charge method, as experience has demonstrated that, using a low voltage, the readings at charge and discharge are practically the same, as the effect of absorption is negligible. With some of the insulating compounds used the effect of the high-voltage test is to temporarily increase the capacity, and it will frequently happen that the first measurement may be higher than that required by the specifications, but if the cable is allowed to stand for 24 hours the capacity will probably drop to the limit prescribed by the specifications. When the first measured capacity is too high it should be remeasured after 24 hours. When the capacity of long lengths of cable is being tested, either Thompson's or Gott's method is preferable to using a shunted galvanometer. In measuring insulation resistance, especially in damp weather, care should be taken to thoroughly insulate the galvanometer, keys, and shunt box. The leakage from the galvanometer can be avoided by connecting the leveling screws together and then joining them to the insulated terminal of the battery key and by supporting the leveling screws on ebonite buttons.

In making the insulation measurement care should be taken to properly prepare the ends of the core, so as to avoid surface leakage. The ends should be freshly cut in conical form, allowing 2 or 3 inches of the copper core to project so that the lead may be attached, care being taken that the freshly cut surface is not touched by the fingers. It is a good plan to dry both ends with an alcohol lamp, taking care that the flame does not come close enough to injure the compound.

The copper resistance is measured by the usual bridge method.

In all cases, at the beginning of each series of tests, the leakage of the leads, their capacity, and resistance are determined.

The results of each day's work should be entered on the test sheet, and when the cable is finally completed the data in respect to each core and finished cable length should be entered on the record sheet, a copy of which should be forwarded with each shipment, one retained in the office of the officer making the inspection, and the third copy furnished the Chief Signal Officer of the Army.

While the logarithmic method of computation is used in the illustrations which follow, it is much better to calculate the results with the Thatcher slide rule, which reads to four places of figures accurately, and by approximation to the fifth. One setting of this rule will serve for an entire series of calculations and effects a very great saving of time.

In measuring capacity the method employed is the ordinary ballistic one, using a battery of but two or three volts. A deflection is obtained by charging a standard condenser, usually one-third of a microfarad, in series with a galvanometer, battery, and key. The first throw of the galvanometer is noted and the deflection for one microfarad calculated and entered on the test sheet. The cable is then substituted for the standard condenser, earthing one end and the battery, and the deflection read and noted.

In measuring insulation resistance the galvanometer constant is first obtained by connecting the high resistance, usually a megohm, in series with the battery of 100 volts, and galvanometer, which should be shunted with the $\frac{1}{1000}$ shunt, and observing the deflection, which is then corrected for the shunt and noted on the test sheet. The leakage of the leads, with the same voltage, is then obtained. The lead is then connected to the cable, the battery applied, the zinc pole to the cable, and the other side grounded. The deflection of the galvanometer is noted at the expiration of a minute, and this deflection is the one from which the insulation resistance is calculated. It is well, however, to allow the battery to remain on for several minutes, noting the deflection at the end of each minte. This deflection should fall in a gradual and even manner. In the case of one of the compounds used, viz, that of the Safety company, the deflection should halve itself, i. e., the insulation should double itself at the third and fifth minutes.

After the insulation resistance has been obtained, the bridge is used to measure the copper resistance of the core and the leads. The temperature of the tank is taken and noted. All measurements are made with the core or cable in the tank after it has been immersed for 24 hours, as the rubber compound will not attain its proper insulation at any given temperature until several hours after it has reached that temperature. There is always more or less uncertainty about the temperature, as the water in the different parts of the tank may not be at the same temperature; consequently care should be taken to get a uniform temperature throughout the tank. As there is less uncertainty with the core than with the finished cable, the copper resistances of the core reduced to the standard temperature may be, in case of doubt, taken as a base for calculating the test temperature of the finished cable.

The insulation resistance of rubber compound varies with the temperature, increasing as the temperature diminishes and decreasing as it rises. The temperature law of variation of the insulation resistance can be taken approximately as a simple logarithmic law. The insulation resistance, diminishing in equal ratio with an increase in the temperature, can be written in the form $R=rC^t$, in which R is the resistance at the higher temperature, r the resistance at the lower temperature, t the difference in temperature in degrees Fahrenheit, and C a constant, depending on the nature of the insulation compound, which, for the Safety company, can be assumed as 0.973, and for the Kerite 0.939. For reducing the insulation resistance at any observed temperature to that of the standard temperature, 60° F., it is necessary to have a factor to multiply the resistance of the observed temperature. The Okonite, Habirshaw, and Bishop companies have found that their compounds follow the logarithmic law sufficiently close for all practical purposes. The coefficients of a number of compounds, according to this simple logarithmic law, are plotted in following table on logarithmic paper designed by the late Mr. Townsend Wolcott. The ordinates represent the temperature and are plotted arithmetically, while the abscissæ, the ratio of the insulation resistance at 60° F. to that at the temperature of observation, are plotted logarithmically. The resistance at 60° F., being taken as unity, its logarithm, zero, is in the center of the paper, and the scale extends on the right to log. $\sqrt{10}$, and on the left to log. $\sqrt{0.1}$.

The following table gives the factors for reducing the insulation resistance of the Okonite, Habirshaw, and Bishop companies' compounds to 60° F. according to the simple logarithmic law, these compounds doubling their insulation with a difference of temperature of 27° F.

Factors for reducing the insulation resistance of the Okonite, Habirshaw, and Bishop compounds to 60° F.

Temperature.	K.	Log K.	Temperature.	K.	Log. K.
°F.			*°F.*		
50	0.773	9.888401	66	1.167	0.067071
51	.793	9.899629	67	1.197	.078094
52	.814	9.910802	68	1.228	.089198
53	.835	9.921906	69	1.260	.100371
54	.856	9.932929	70	1.293	.111599
55	.879	9.944240	71	1.326	.122544
56	.902	9.955460	72	1.361	.133858
57	.925	9.966576	73	1.396	.144885
58	.949	9.977572	74	1.433	.156246
59	.974	9.988853	75	1.470	.167317
60	1.000	.000000	76	1.508	.178401
61	1.026	.011147	77	1.547	.189490
62	1.053	.022428	78	1.587	.200577
63	1.080	.033424	79	1.629	.211921
64	1.108	.044540	80	1.671	.222976
65	1.137	.055760			

As the result of careful observations of the temperature variation of the Safety and Kerite compounds, Mr. Townsend Wolcott, formerly electrical engineer, Signal Corps, gives the following formula:

$$\text{Log.}\left(\frac{R_t}{R_{60}}\right)=(.00802488+.000044619t)=(60-t)$$

$$\text{Log.}\left(\frac{R_t}{R_{60}}\right)=(.00845964+.000286604t)=(60-t)$$

in which R_t is the resistance at the temperature of observation and R_{60} is the resistance at 60° F. Calling the reciprocal of this ratio K, the following table has been calculated for the Safety and Kerite compounds:

Temperature coefficient for the reduction of insulation resistance to 60° F.

Temperature.	Safety. K.	Safety. Log. K.	Temperature.	Kerite. K.	Kerite. Log. K.
° *F.*			° *F.*		
50	0.789	9.897441	50	0.591	9.772110
51	.807	9.907300	51	.619	9.792325
52	.826	9.917240	52	.650	9.813104
53	.845	9.927277	53	.683	9.834457
54	.865	9.937396	54	.718	9.856390
55	.886	9.947609	55	.756	9.878890
56	.907	9.957908	56	.797	9.901968
57	.929	9.968296	57	.823	9.925615
58	.952	9.978776	58	.891	9.949836
59	.975	9.989343	59	.943	9.974632
60	1.000	0.000000	60	1.000	0.000000
61	1.025	.010746	61	1.061	.025941
62	1.050	.021582	62	1.128	.052456
63	1.080	.033505	63	1.201	.079545
64	1.105	.043500	64	1.280	.107204
65	1.134	.054625	65	1.367	.135755
66	1.163	.065714	66	1.460	.164244
67	1.194	.077098	67	1.562	.193627
68	1.226	.088624	68	1.673	.223584
69	1.258	.099927	69	1.796	.254106
70	1.292	.111482	70	1.928	.285210
71	1.328	.123120	71	2.074	.316827
72	1.364	.134844	72	2.234	.349128
73	1.401	.146666	73	2.409	.381953
74	1.441	.158564	74	2.602	.415338
75	1.481	.170565	75	2.814	.449310
76	1.523	.182640	76	3.046	.483760
77	1.566	.194820	77	3.303	.518959
78	1.611	.207090	78	3.586	.554652
79	1.657	.219431	79	3.899	.590900
80	1.705	.231888	80	4.244	.627740

The resistance of copper increases with the increase of temperature. In order to reduce copper resistances at any temperature between 50° and 80° F. to 60° F., the following table has been calculated in which δ is the factor by which the resistance at the observed temperature should be multiplied to reduce it to 60° F.

Reduction of copper resistance to 60° F.

Temperature.	δ.	Log. δ.	Temperature.	δ.	Log, δ.
° *F.*			° *F.*		
50	1.022	0.009451	66	0.9875	9.994519
51	1,019	.008174	67	.9847	9.993614
52	1.017	.007321	68	.9834	9.992707
53	1.015	.006466	69	.9813	9.991805
54	1.013	.005609	70	.9793	9.990903
55	1.011	.004751	71	.9773	9.990003
56	1.009	.003891	72	.9752	9.989107
57	1.007	.003029	73	.9732	9.988211
58	1.004	.001734	74	.9712	9.987317
59	1.002	.000868	75	.9692	9.986425
60	1.000	.000000	76	.9672	9.985535
61	.9977	9.999081	77	.9653	9.984647
62	.9958	9.998165	78	.9633	9.983760
63	.9944	9.997551	79	.9613	9.982857
64	.9916	9.996338	80	.9594	9.981993
65	.9895	.995428			

The two following tables illustrate the manner in which the records of factory tests are kept, and the next is an example of a record sheet.

In the following where miles are indicated, statute miles are meant unless nautical miles are specifically mentioned. Multiply statute miles by the factor 1.1538 to obtain nautical miles.

Record of cable tests for Signal Corps, U. S. Army.

[Date, July 5, 1901; place of test, Seymour, Conn.; manufacturer, W. R. Brixey; type of wire, core.]

Galvanometer constants {45,000 divisions through 2.064 megohms, 92,880 divisions through 1 megohm. 326 divisions through ⅓ microfarad, 978 divisions through 1 microfarad. Temperature, 75° F.

Leads {Leakage, 12 divisions. Conductor resistance, 1.64 ohms. Capacity, 5 divisions.

Reel or section No. —.			Capacity.				Insulation.					Conductor resistance.			
Core length.		Length in feet.	Observed deflection.	Corrected deflection.	Total microfarads.	Microfarads per mile.	Observed deflection.	Corrected deflection.	Total insulation temperature of observation.	Total insulation at 60° F.	Insulation per mile at 60° F.	Total resistance.	Corrected for leads.	Total resistance at 60° F.	Resistance per mile at 60° F.
Miles.	No.														
1.000	116	5,280	296	291	0.298	0.298	197	185	502.1	1,426	1,426	11.37	9.73	9.43	9.43
1.004	117	5,300	292	287	293	.292	172	160	580.5	1,649	1,656	11.34	9.70	9.40	9.36
1.002	118	5,290	295	290	.297	.296	124	112	829.4	2,356	2,361	11.26	9.62	9.32	9.30
.991	119	5,230	287	282	.288	.291	156	144	645	1,832	1,815	11.17	9.53	9.24	9.32
1.004	120	5,300	294	289	.296	.295	130	118	787.1	2,236	2,245	11.37	9.73	9.43	9.39
1.009	121	5,330	294	289	.296	.293	169	157	591.6	1,681	1,696	11.40	9.76	9.46	9.38
1.007	122	5,316	299	294	.301	.299	163	151	615.2	1,747	1,759	11.31	9.67	9.37	9.31
1.003	123	5,296	295	290	.297	.296	143	131	709.1	2,015	2,021	11.26	9.62	9.32	9.29
1.006	124	5,296	290	285	.291	.286	174	162	573.4	1,629	1,639	11.24	9.60	9.30	9.24
.977	125	5,160	290	285	.291	.298	128	116	800.7	2,275	2,223	11.15	9.51	9.22	9.44

Observations by Townsend Wolcott; calculations by T. W.

[Date, August 23, 1900; place of test, New York City; manufacturer, Safety Insulated Wire and Cable Company; type of wire, finished cable.]

Galvanometer constants {185,000 divisions through 1 megohm. 256 divisions through 0.3 microfarad, 853 divisions through 1 microfarad. Temperature, 78° F.

Leads: Leakage, 29 divisions; conductor resistance, 1.38 ohms.

Reel or section No. 64.		Capacity.				Insulation.					Conductor resistance.			
Core length No.	Length in feet.	Observed deflection.	Corrected deflection.	Total microfarads.	Microfarads per mile.	Observed deflection.	Corrected deflection.	Total insulation temperature of observation.	Total insulation at 60° F.	Insulation per mile at 60° F.	Total resistance.	Corrected for leads.	Total resistance at 60° F.	Resistance per mile at 60° F.
....	....	1,800	1,800	2,100	0.413	970	941	196	510	1,621	94.5	93.12	87.66	17.16
Total {26,765 feet. 5.107 miles.														

Observations by S. R.; calculations by S. R.

Record sheet.

[Manufacturer, Safety Insulated Wire and Cable Company; type, deep-sea cable; loaded on U. S. Army transport *Burnside*.]

Section No.	Length (miles).	Capacity.				Insulation.		Copper.			
		Core.		Cable.		Core, per mile.	Cable, per mile.	Core.		Cable.	
		Absolute.	Per mile.	Absolute.	Per mile.			Absolute.	Per mile.	Absolute.	Per mile.
85	5.138	1.988	0.387	1.775	0.345	1,613	1,073	90.26	17.58	90.32	17.58
86	5.097	1.944	.391	1.635	.321	1,421	1,150	89.31	17.52	89.60	17.58
87	5.082	1.775	.349	1.525	.300	1,269	1,119	86.36	17.57	88.92	17.50
88	5.125	2.063	.402	1.610	.314	1,350	778	86.99	17.55	88.47	17.26
89	4.855	1.750	.360	1.480	.305	1,409	1,108	85.12	17.13	85.46	17.61
90	4.853	1.750	.360	1.500	.309	1,416	1,077	85.05	17.52	83.95	17.30
91	4.848	1.795	.370	1.613	.333	1,416	1,122	85.39	18.01	83.95	17.20
92	4.841	1.964	.405	1.709	.352	1,637	1,312	84.95	17.53	84.25	17.37
93	4.877	1.807	.370	1.590	.326	1,487	1,232	85.24	17.47	85.31	17.49
94	5.133	1.889	.368	1.702	.331	1,510	1,099	89.97	17.53	89.32	17.40
95	5.138	2.115	.411	1.596	.311	1,610	1,043	90.15	17.54	88.46	17.30
96	5.097	1.863	.365	1.630	.320	1,261	1,306	89.11	17.48	87.98	17.26
97	5.112	2.012	.393	1.637	.320	1,454	1,039	90.34	17.68	91.34	17.87
98	5.098	1.978	.388	1.699	.333	1,699	1,306	89.50	17.56	88.40	17.35
99	5.107	1.884	.369	1.589	.311	1,267	852	89.14	17.46	90.32	17.68
100	5.138	2.172	.423	1.633	.318	1,358	1,205	90.22	17.56	89.40	17.40

The following computation illustrates the logarithmic method of calculating the data contained in record sheet of Safety Company cable.

CAPACITY.

Log. 1800=3. 255273
Log. 853=2. 930949

Absolute capacity, 2.110 . 324324
Log. 5.107= . 708166

Capacity per mile, 0.413 1. 616158

INSULATION RESISTANCE.

970—29=941
Log. 185000=5. 267172
Log. 941=2. 973590

Insulation at temperature of observation, 196 2. 293582
Log. K = . 207090

Total insulation at 60° F., 510 2. 501672
Log. 5.107= . 708166

Insulation resistance per mile, 1621 3. 209838

COPPER RESISTANCE.

	94.5—1.38=93.12
	Log. 93.12=1.969043
	Log. δ =9.983760
Total resistance at 60° F., 87.66	1.942803
	Log. 5.107= .708166
Resistance per mile at 60° F., 17.16	.234637

DATA FOR SAFETY INSULATED WIRE AND CABLE COMPANY'S COMPOUND.

Specific gravity of compound, 1.646.

Weight per cubic foot of compound, 103 pounds.

Capacity per mile, solid conductor$=\dfrac{.2063}{\log. D-\log. d}$

Capacity per nautical mile, solid conductor$=\dfrac{.2329}{\log. D-\log. d}$

Capacity per mile, 7-stranded conductor$=\dfrac{.2063}{\log. D-\log. 2.27\ \delta}$

Capacity per nautical mile, 7-stranded conductor$=\dfrac{.2329}{\log. D-\log. 2.27\ \delta}$

Insulation resistance per mile, solid conductor=1982 (log. D—log. d).

Insulation resistance per nautical mile, solid conductor=1756 (log. D—log. d).

Insulation resistance per mile, 7-stranded conductor=1982 (log. D—log. 2.27 δ).

Insulation resistance per nautical mile, 7-stranded conductor=1756 (log. D—log. 2.27 δ).

Weight per mile of compound, solid core=2956 (D^2—d^2).

Weight per mile of compound, 7-stranded conductor=2956 (D^2—6.9 δ^2).

D=outside diameter of insulation.
d=diameter of solid conductor.
δ=diameter of single strand.

DATA FOR KERITE.

Specific gravity of compound, 1.233.

Weight per cubic foot, 77 pounds.

Capacity per mile, solid conductor$=\dfrac{.1738}{\log. D-\log. d}$

Capacity per nautical mile, solid conductor$=\dfrac{.1962}{\log. D=\log. d}$

Capacity per mile, 7-stranded conductor$=\dfrac{.1738}{\log. D-\log. 2.27\ \delta}$

Capacity per nautical mile, 7-stranded conductor$=\dfrac{.1962}{\log. D-\log. 2.27\ \delta}$

Insulation resistance per mile, solid conductor=2147 (log. D—log. d).

Insulation resistance per nautical mile, solid conductor=1602 (log. D—log. d).

Insulation resistance per mile, 7-stranded conductor=2147 (log. D—log. 2.27 δ).

Insulation resistance per nautical mile, 7-stranded conductor=1902 (log. D—log. 2.27 δ).

Weight per mile of compound with solid core=2211 (D^2—d^2).

Weight per mile of compound, 7-stranded conductor=2211 (D^2—6.9 δ^2).

D=outside diameter of insulation.
d=diameter of solid conductor.
δ=diameter of single strand.

Conversion tables.

Statute miles to nautical miles.		Nautical miles to statute miles.	
Statute miles.	Nautical miles.	Nautical miles.	Statute miles.
1	0.8674	1	1.1528
2	1.7348	2	2.3057
3	2.6023	3	3.4585
4	3.4697	4	4.6114
5	4.3371	5	5.7642
6	5.2045	6	6.9170
7	6.0719	7	8.0699
8	6.9394	8	9.2127
9	7.8068	9	10.3756
Statute miles to kilometers.		**Kilometers to statute miles.**	
Miles.	**Kilometers.**	**Kilometers.**	**Miles.**
1	1.60935	1	0.62137
2	3.21869	2	1.24274
3	4.82804	3	1.86411
4	6.43739	4	2.48548
5	8.04674	5	3.10685
6	9.65608	6	3.72822
7	11.26543	7	4.34959
8	12.87478	8	4.97096
9	14.48412	9	5.59233

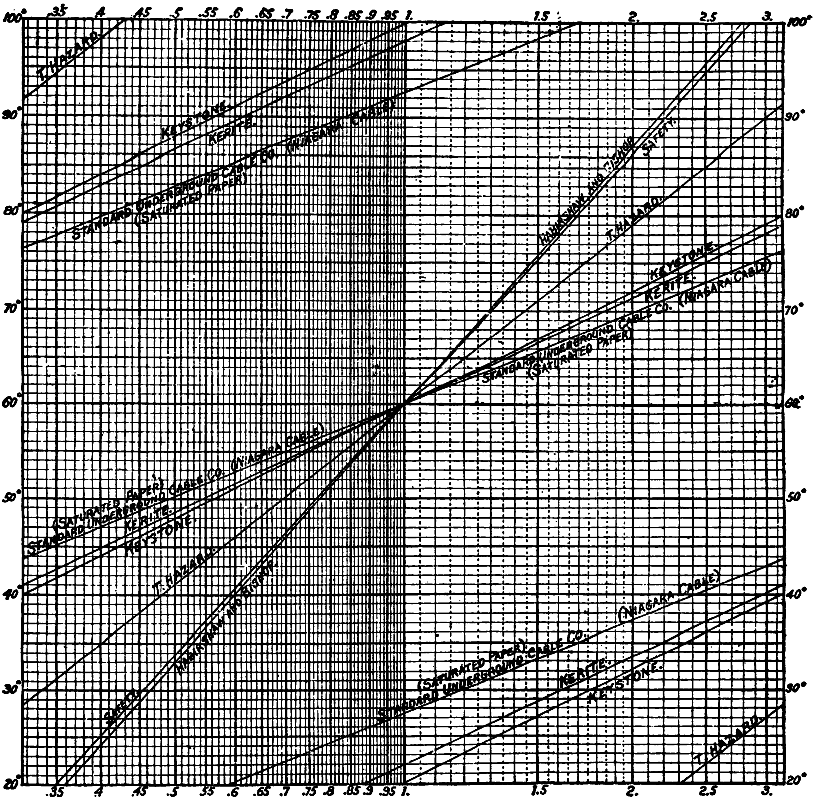

FIG. 4-43.—COEFFICIENTS FOR REDUCING INSULATION RESISTANCE AT DIFFERENT TEMPERATURES TO 60° F.

CHAPTER 5.

AERIAL LINE CONSTRUCTION.

The following, which appeared in "Telegraph and Telephone Age, May 16, 1915," should be noted, as it coincides with the opinion of those who have had wide experience in line construction for the Signal Corps:

MODERN LINE CONSTRUCTION.

Present-day telegraph-line construction is in marked contrast with the notions prevailing a few years ago. High poles were then considered to be the proper way of placing a line out of harm's way, but, with the constant accretion of wires and the increasing frequency of wind and sleet storms, a revision of former methods of construction became necessary. The only way to render a line proof against the extraordinary strains put upon it under modern conditions is to use shorter and stouter poles. This now is the rule, with beneficial results, although the mechanical load and the violence of nature's outbreaks still have to be reckoned with. The shorter poles are more durable and better able to carry their burden and withstand the attacks of the elements.

Where aerial construction is employed, the system should be designed to utilize cable, as far as practicable, thereby avoiding a large number of aerial wires. Lightning arresters should always be installed to protect cables and telephones connected to an aerial circuit. Outside distributing wire is provided for leading from the pole to substations of post telephone systems.

ERECTION OF LINE.

The route of the line having been decided upon and the materials prepared or procured, a competent person should proceed to measure the distance and indicate, by stakes, the places at which poles are to be erected. When the line follows highways or other defined routes, he will necessarily be governed by the bounds of such route and must place his stakes within those bounds and in such a manner as to avoid, as far as possible, danger to the line from passing vehicles.

As a general rule in open (unfenced) country the stakes may be placed in straight lines, but where there is a well defined and traveled road the line of stakes must follow the general direction of such road and be set at such distance from it that the line when completed shall not be exposed to injury from passing vehicles, or, in case a wire should become detached from the insulators, it can not by any chance hang in the road and interfere with or endanger traffic. With this in view, the line must be so placed as to be readily inspected and examined by repair men from the road. Whenever practicable, the line should be removed from the road a distance of about 30 feet. Roads should never be crossed unless necessary to avoid bad ground or trees which are too numerous to cut away, or to make material saving by shortening the line. Such crossings should be made at half a right angle. In rolling country, poles should be planted near the crests of hills and not on each side, as in the latter case the wire will not be raised sufficiently high above the ground to be free from danger of being broken by passing herds or vehicles. As far as practicable, grade the line by using the longer poles in hollows and the shorter ones on high ground.

At all crossings the distance between poles should be shortened and the height of wire above crown of road be not less than 18 feet.

POLES.

Poles should be preferably of red cedar, black locust, or chestnut. Should these not be procurable, or only at too great cost, recourse may be had to other kinds of timber, such as redwood, white cedar, red cypress, yellow cypress, tamarack, fir, larch, spruce, white or post oak, sassafras, and others, from which good service may be expected.

All poles should be of the first quality of live green timber, free from rot, and sound and substantial in every respect. Each pole should contain the natural butt of the tree and have an approximately uniformly decreasing cross section from butt to top.

All poles should be cut between November 1 and March 1, and should be free from all bark and soft wood. All knots should be trimmed closely and smoothly. The sizes and dimensions of poles should conform to the table below.

When octagonal poles are ordered they should be of the same material as specified for standard poles, and should conform in general to the dimensions in the table.

Desired dimensions of wood poles.

Length of poles.	Circumference.		Length of poles.	Circumference.	
	At top.	At 6 feet from bottom.		At top.	At 6 feet from bottom.
Feet.	*Inches.*	*Inches.*	*Feet.*	*Inches.*	*Inches.*
20	14	24	35	22	37
20	16	25	35	25	40
25	16	25	40	22	40
25	19	27	40	25	43
25	22	30	45	22	45
30	19	30	45	25	46
30	22	34	50	22	46
30	24	36	50	25	48

PRESERVATIVE TREATMENT OF WOODEN POLES.

Results of an experience with treated poles over a period of 18 years by the American Telegraph & Telephone Co. show that the life of poles is materially increased by such action.

It is believed to be impracticable to state the magnitude of the increase in life of poles obtained by the use of preservatives, as the increase is dependent upon so many factors. The amount of preservative and depth of impregnation, the kind of wood, and the nature of soil are all factors which enter in computing the increase of life by using preservatives. Therefore, suffice it to state that by using preservatives the life of poles, all things being equal, is increased to such an extent that for permanent lines under ordinary conditions the extra cost occasioned by use of preservative is more than compensated for. It has been found that preservatives not only delay the starting of decay but when started the decaying effect is retarded.

Of the factors enumerated above the most important one by far is the first one shown, namely, the amount of preservative per given cubic foot of wood and depth of impregnation, and while one of these seems to be dependent upon the other, it will be understood that the result of a heavy coat of preservative on outside is not so efficient as the same amount forced into the pores of the wood.

There are three methods of applying preservative in use at this time—the brush, the open tank, and the pressure process. With the brush method the preservative is applied with a brush, the part of pole to be treated first being thoroughly cleaned. With the open-tank method the pole or butt of pole is immersed in a tank of preservative, the preservative being kept hot until bubbling caused by air or water in poles ceases. The hot preservative is then allowed to cool, and the vacuum created in the cells of the pole timber while heating assists in drawing preservative into the wood. The penetration with the latter method has a range from one-fourth to one-half inch, while in the former approximately one-sixteenth to somewhat under one-fourth inch may be obtained. With the pressure process a greater penetration is obtained, but due to cost the first two methods are more popular.

Due to short life of pine poles, both above and below ground, it is believed that such poles should be treated their entire length if anything approaching a permanent line is constructed with such material. The part of any set pole most susceptible to decay is a section from a few inches above ground line to 2 or 3 feet below ground line, and where it is impracticable to treat wooden poles thoroughly, treatment of this section will materially add to the life of the poles.

CONCRETE POLES.

In the Tropics, and occasionally in other places, it is more advantageous to manufacture reinforced concrete poles for post telephone systems. Concrete poles are not recommended for telegraph lines on account of the difficulty of transportation and delivery along the route. The forms may be easily prepared by using 2-inch plank, free from knots, and dressed on one side. Three pieces only are required, the top being left open for pouring the concrete. The forms are held in place by side and top cleats secured to prevent the form spreading when the concrete is poured.

The longitudinal reinforcement consists of four square or twisted steel bars, three-eighths inch bars being about the proper size for 24-foot poles, and one-half inch bars for longer poles. The four bars are set about one-half inch from each corner, being spaced by a piece of wood at each end of the form, with holes to take the ends of the rods. It is also necessary to bind the four rods together by iron wire at four or five points throughout the length. The reinforcing rods are held in position at various points by wooden blocks or wire to prevent sagging. These are removed as the concrete is poured.

A very wet mixture of concrete should be used, proportioned one part cement, two parts sharp sand, and four parts crushed stone of less than one-half inch size. It is important to have sharp sand. Gravel instead of crushed stone will give satisfactory results, but should be cleaned well. The side walls may be removed the next day after pouring. After the fourth day the concrete is sufficiently set to remove the pole from the bottom form by sliding it endwise, using heavy ice tongs. A small amount of troweling is necessary to finish up the surfaces before the concrete is entirely set. The pole should be allowed to cure about 30 days before use. Wooden pins should be placed in the form before pouring the concrete, for bolt holes and pole steps, if they are desired.

Concrete poles having a length of 24 feet should be about 8 by 8 inches at the base and 5 by 5 inches at the top. Beveled corners improve the appearance. Twenty-four-foot poles weigh approximately 1,100 pounds, and 30-foot poles 1,400 pounds. Twenty-four-foot poles should be set approximately 4 feet in the ground, and 30-foot poles approximately 5 feet in the ground. A 24-foot pole having an 8-inch square base and a 5-inch square top requires about 7 cubic feet of concrete.

DIGGING HOLES.

The depth to which poles should be set depends upon the character of the soil in which they are placed, the height of the pole, and the load it is to carry. In rock, gravel, or stiff clays a less depth is sufficient than in light loam or sand. The following table gives the depths for average conditions:

Length of pole.	Depth in ground.	Depth in solid rock.
Feet.	*Feet.*	*Feet.*
18	[1] 3 [2] 3½	3
20	4	3
22	4	3
25	5	3
30	5½	3½
35	6	4
40	6	4
45	6½	4½
50	7	4½

[1] On straight lines. [2] On corners.

A foreman follows with a sufficient number of men equipped with digging bars, spoon shovels, the ordinary long-handled shovel, or post-hole diggers, where the soil will admit of their use. This party digs the holes for the poles as marked out by the stakes. If there is a sod, one of the men, equipped with an ordinary spade, may be sent ahead to remove it, indicating the size of the hole to be dug and facilitating the work by performing a part thereof for which the bars and spoons are not well adapted. The foreman must see personally that the holes are put down to the proper depth. He will have direction of the force and be held responsible for good service. For poles at crossings, curves, and long spans the holes must be dug to a depth corresponding to the strain to be brought upon them.

POLE SETTING.

All pole holes should be dug large enough to admit the pole without the necessity of cutting away the butt and should allow space to move the pole about for bringing it into line. The size of the hole should be such that the tamping bar may be used full depth. This matter of thorough tamping as the hole is filled is important to the proper setting of the pole. On straight lines the cross arm should be placed at right angles to the direction of the pole line, the arms on adjacent poles facing in opposite directions. At line terminals the cross arms on the last two or three poles should be placed on the sides of the poles which face the terminal. On curves the cross arms should be placed on the sides of the poles which face the middle of the curve. On straight lines the poles shall be set vertically. It is advisable that the corner poles should be given a slight rake when set, varying with conditions, from 10 to 20 inches. After the pole has been placed in position, the hole filled, and the earth well tamped, the soil should be well banked up about the pole and firmly packed in place. This is to prevent a depression forming about the base of the pole, due to subsequent settling of the earth. In filling holes the coarse material, soil or gravel, should be used at the top of the holes. Where poles are set in rock, the pieces should be wedged in firmly about the pole. It will usually be found that there are more or less pronounced curves in all wooden poles. When setting the poles these curves should be so placed as to be least apparent when viewed from the direction of the line.

In grading poles to obtain uniform height of lead it is proper to cut the pole as a last resort only when shorter poles are not at hand. If the difference in height is only 1 or 2 feet, it may be taken care of by digging the hole deeper. When necessary to cut a pole the top, and not the butt, should be cut.

NUMBER OF POLES.

The number of poles to be provided depends upon the character of the country and upon the number of wires or cables to be supported. No less than the equivalent of 35 poles per mile must be used; but in timbered country, with crooked roads and heavy leads, it may be necessary to increase this number to 45 or even more in special cases.

DELIVERY OF POLES.

The poles should be delivered as soon as practicable after the holes have been dug, with the butt of the pole by the hole and the top in the direction from which the raising party will come. No equipment is necessary for this labor, except the means used for the transportation of the poles and carrying hooks with which to move them as required after unloading. For crossings and long spans the heaviest and longest poles should be selected; for angles and sharp curves, select the stoutest.

PREPARATION OF POLES.

When practicable, the poles must be cut when the sap is down, and the bark removed, and allowed to season before they are placed in the line. This increases the durability of most kinds of poles and facilitates their transportation and erection. The tops of the poles should be roofed, as shown in figure 5–1, so that they will effectively shed rain and snow.

LIGHTNING RODS.

A lightning rod is sometimes provided for every fifth to tenth pole of all aerial lines. This rod may consist of a piece of No. 6 galvanized-iron wire extending not less than 12 inches above the roof of the pole and attached to the sides thereof by means of staples about 1 foot apart. The lightning rod should extend continuously down the entire length of the pole, and may be soldered to a ground rod driven into the earth near the base of the pole or may be continued to the base of the pole and there end in a small coil of wire, to give good surface contact with the earth. This wire should be kept as straight as possible without turns or coils in its length and should be installed before the pole is erected.

CROSS ARMS.

The standard cross arms supplied by the Signal Corps are indicated in the following table:

Dimensions of standard cross arms.

Length in feet.	Number of pins.	Pin spacing.		
		Ends.	Sides.	Centers.
3	2	4	....	28
4	4	4	12	16
6	6	4	12	16
8	8	4	12	16
10	10	4	12	16

FRAMING POLES.

All poles supporting cross arms should be framed in the following manner: Raise the pole at the top and place it in a framing buck or horse so that the heaviest sag or curve will be nearest the ground. If the pole be crooked or badly shaped, it should be turned with a cant hook until the best side for framing is uppermost and the pole held rigidly in place. In this position the pole should be roofed. After the roofing has been done, the gains should be cut. These may be leveled with a straightedge or sighting stick. To bore holes for cross-arm bolts, a line should be set off from the center of the top of the pole to the center of the butt and the bolt-hole center laid off along this line. A half-inch hole for steps may be bored at right angles to the line or in line with the cross arms, beginning 18 inches from the lowest cross arm and continuing 18 inches apart or 36 inches apart when measured on the same side of the pole until a point 8 feet from the ground is reached.

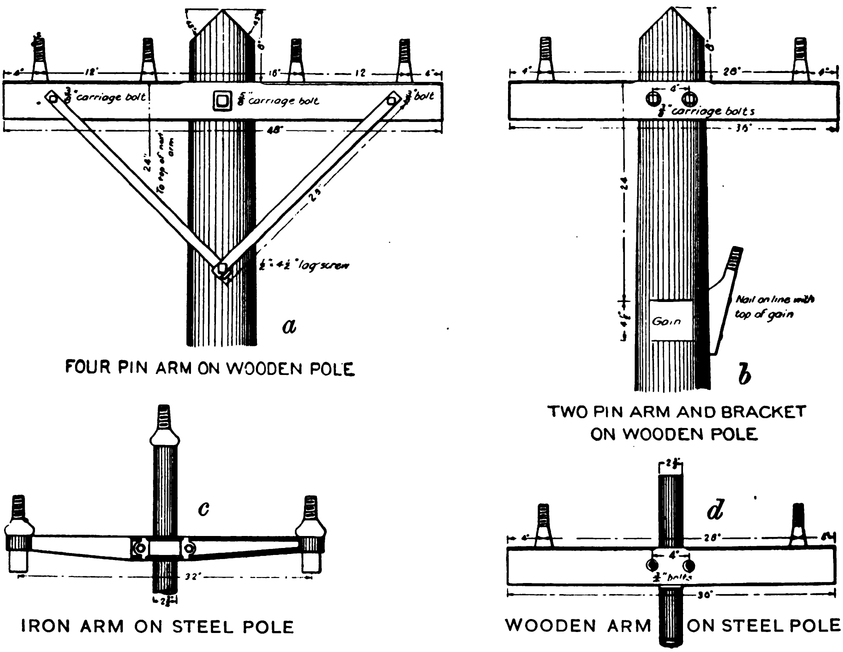

Fig. 5–1.—AERIAL LINE CONSTRUCTION, PREPARATION OF POLES.

All cross arms for carrying four wires and upward must be braced. (Fig. 5–1.) Gains for cross arms will not exceed in any case 1¼ inches in depth. The distance from the upper side of the top gain to the extreme top of the pole will be 8 inches, and the distance between gains from center to center 2 feet. Cross-arm braces should be attached to the face of the pole and to the face of the arm. Two lag bolts will be used in all cross arms which are not braced. Cross arms must be placed on opposite sides of alternate poles, except where special conditions of line wires may require otherwise.

Cross arms should be set at right angles to the pole length. This applies as well to corner poles, no matter what the degree of rake.

Cross-arm fixtures should, if practicable, be attached to buildings (other than residences) with bolts passing through the wall. If this is not practicable, large expansion bolts should be used. Window casements or woodwork of buildings should never be used for resisting the strain of the line.

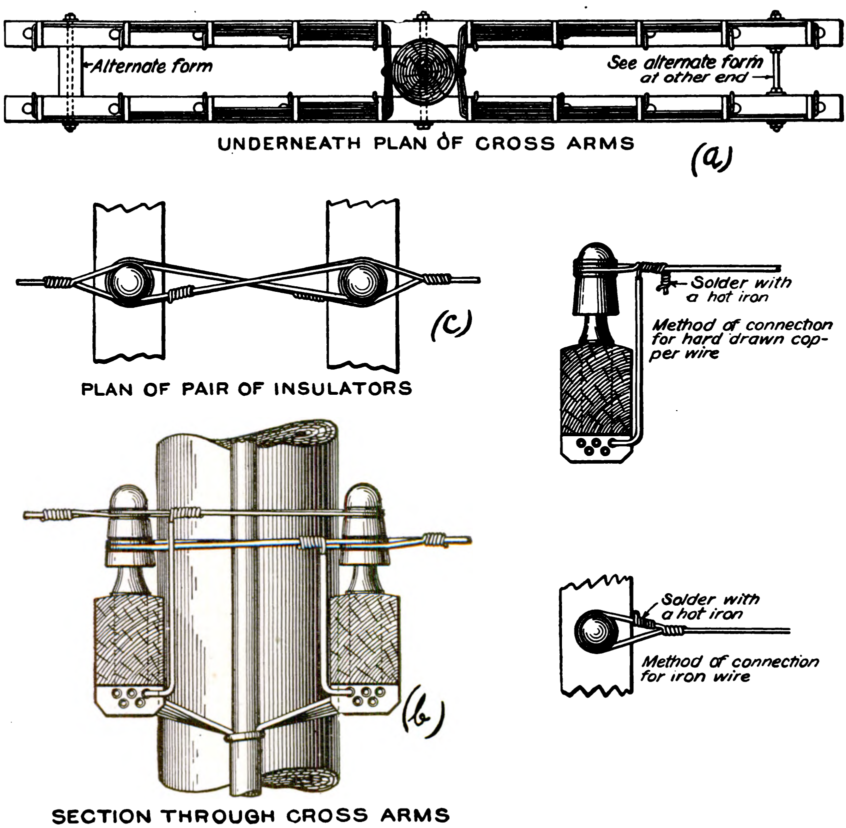

Fig. 5-2.—AERIAL LINE CONSTRUCTION, DOUBLE ARMING.

Telephone line wires should not be terminated at residences by means of cross arms or other type of fixtures attached to walls of residences. The reason for this is that great annoyance may be occasioned by the hum of the line wires. Either outside distributing or outside twisted pair wire should be invariably used for such connections, the line wire being terminated at the cross arm or bracket at nearest pole to residence and the service completed by means of the outside distributing or outside twisted pair wire, which may be made fast to residence by means of a bracket or other type of fixture, and which should enter the residence through two porcelain tubes, each conductor of the duplex wire entering through one of these tubes. If practicable, the tubes should be slanted downward toward the outside of the residence in order to avoid water entering the tubes during stormy weather. If the latter can not be accomplished, the wires should be sagged below the tubes on outside of the building, which will produce the same result. The latter are termed "drip loops."

Poles shall, wherever practicable, be armed before they are erected.

In figure 5–1 are shown the methods of attaching cross arms for leads not exceeding four wires. (*a*) Shows the four-pin cross arm, with braces; (*b*) the two-pin cross arm attached with lag bolts; while (*c*) and (*d*) show the methods pursued in the case of steel poles. These steel poles are only used occasionally to meet special conditions, and are not suitable for supporting more than four wires and should only be installed in hard earth or concrete.

Double arms.—The approved method of installing double cross arms is shown in figure 5–2. The poles upon which the double arms are to be placed should be selected from the heaviest of those available, as these must bear an additional load, and extra strength should be provided. In figure 5–2 is also shown the method of dead ending wires on double cross arms. Where the wires are not dead ended, but pass through, they will be tied to both insulators in the lower groove of the glass if double-groove glasses are in place.

Porcelain-coated bridle rings may be used for supporting bridle wire, instead of cleats as shown in figure 5–2, and copper connectors may be used for splicing bridle wire to hard-drawn copper line wire, instead of as shown in the same figure.

BRACKET LINES.

Where not more than two wires are required on a pole line, oak brackets may be used in place of cross arms. The brackets should be attached to the pole with one 20d. and one 40d. nails and, in general, should be placed as shown

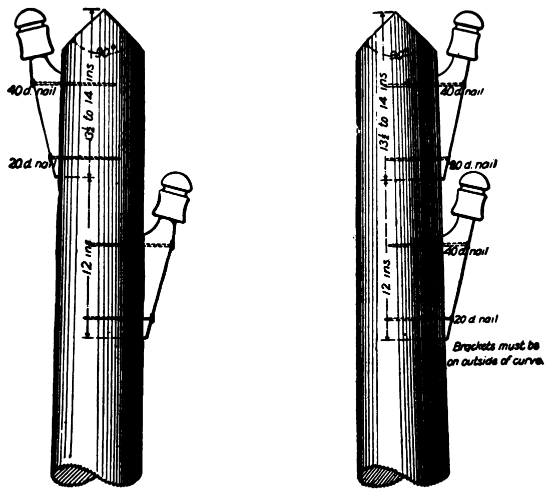

Fig. 5-3.—AERIAL LINE CONSTRUCTION, ATTACHING BRACKETS.

in figure 5–3. Where brackets are placed on poles, which may be used at some later time to support cross-arms, the top end of the bracket should be about level with the correct location of top of the gain, so that the bracket and its wire will not interfere with the subsequent use of the cross arm.

TERMINAL OR OFFICE POLE.

The terminal or office pole of a line carrying a number of wires is the most important part of the line and demands careful attention to secure construction that will be serviceable and easy to maintain. There will be necessity for frequent access to this pole, so that all wiring should be substantial in character and arranged to facilitate repairs and extensions. The office or terminal pole shown in figure 5–5 indicates the construction to be followed in the typical case.

It is probable that the conditions shown in figure 5–5 will not be exactly duplicated in any construction work which may be taken up, but the methods shown should be followed as far as practicable.

The can terminal shown may be installed or use may be made of a cable box shown in figure 5–4. The latter is, in general, considered preferable except in the Tropics. In ordering these boxes the number of pairs to be accommodated should be stated, as well as the number of pairs of lightning arresters and fuses. No aerial line should be cross-connected at a terminal pole or to a central exchange except through fuses and lightning arresters. The terminal or cable-box

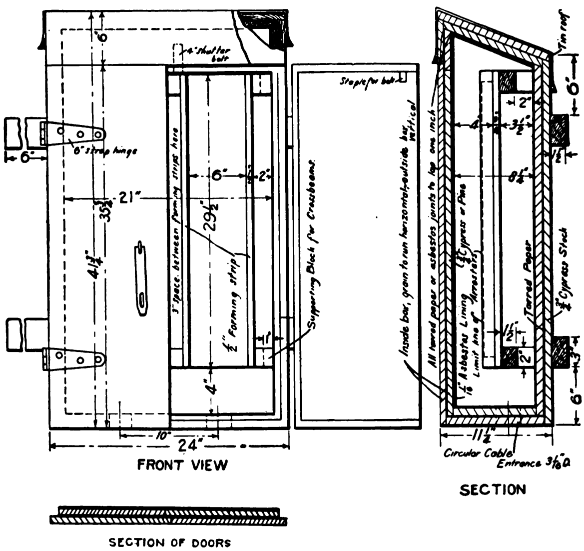

Fig. 5–4.—AERIAL LINE CONSTRUCTION, CABLE BOX.

poles should be stepped, using for this purpose galvanized iron-pole steps, as shown in figure 5–5. These iron-pole steps should not come down to less than 8 feet from the ground. To reach these steps, use may be made of a ladder, or brackets with the tops cut off may be fastened to the pole for footholds, as shown in figure 5–6. Bridle wires, which are used to connect the line wires with can terminal or cable box, run through hardwood cleats, are shown in figure 5–2. Particular attention should be given to all wiring about the pole to see that it fits neatly and is so placed that it will not be injured by the workman in the performance of his necessary duties.

Where the wires which dead end on a double arm lead from one direction only, it will be necessary to counterbalance the strain by running a small guy from this cross arm to the next pole.

Linemen should not use climbers on poles provided with steps unless such use is clearly unavoidable.

GUYS AND ANCHORS.

Wherever a pole line makes a curve, turns a corner, or ends in an office or other terminal pole, particular attention must be given to the matter of proper

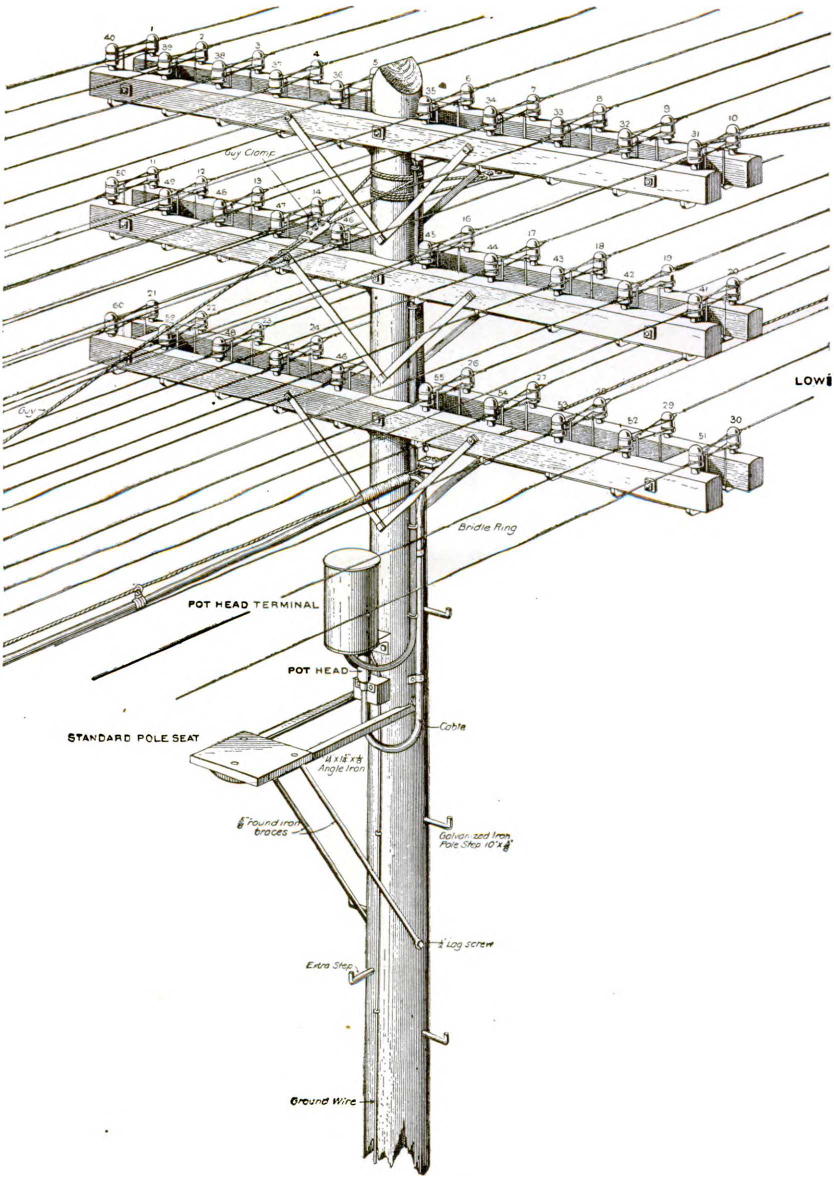

Fig. 5–5.—AERIAL LINE CONSTRUCTION, TERMINAL POLE.

guys and anchors. The following instructions cover the cases usually met with under ordinary conditions. The various methods shown of strengthening the line should be adapted as occasion requires to meet special or unusual cases.

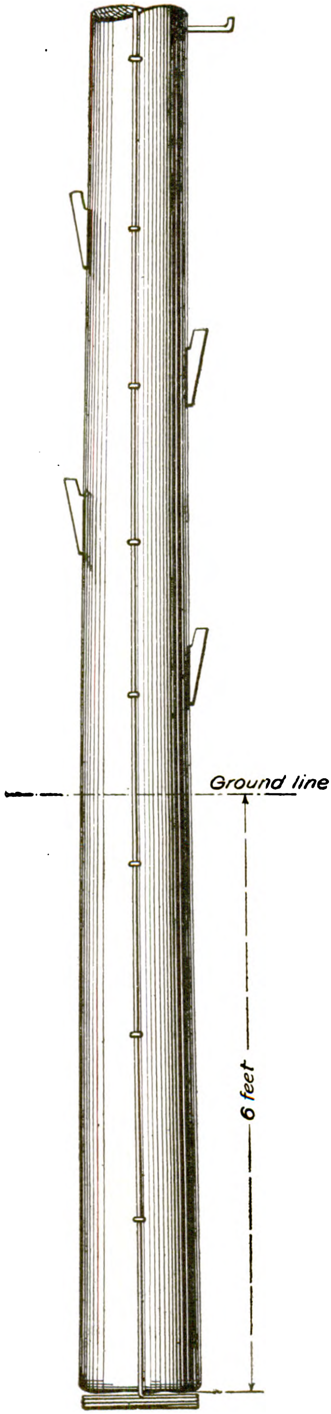

Fig. 5-6.—AERIAL LINE CONSTRUCTION, POLE STEPS.

Guy stubs and anchor logs.—The timber used for guy stubs and anchor logs should conform in all respects with that specified for poles. Anchor logs should be not less than 24 inches in circumference nor less than 4 feet in length.

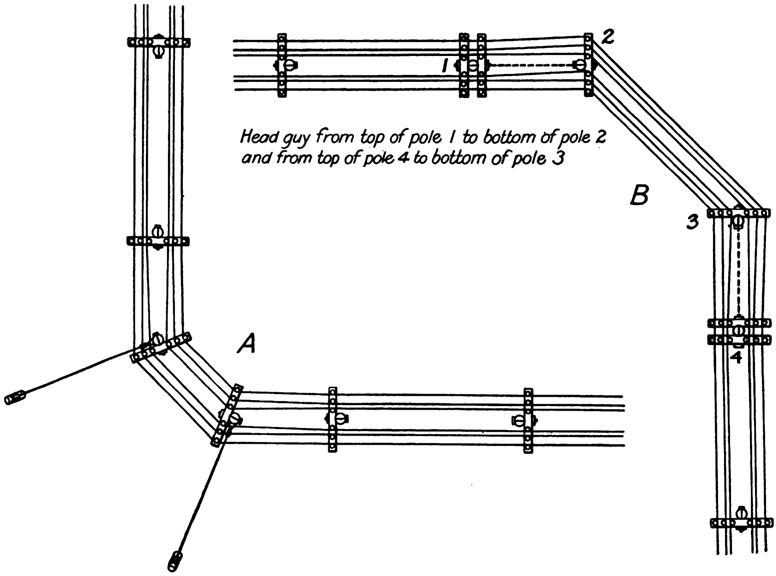

Fig. 5–7.—AERIAL LINE CONSTRUCTION, GUYING AT CORNERS.

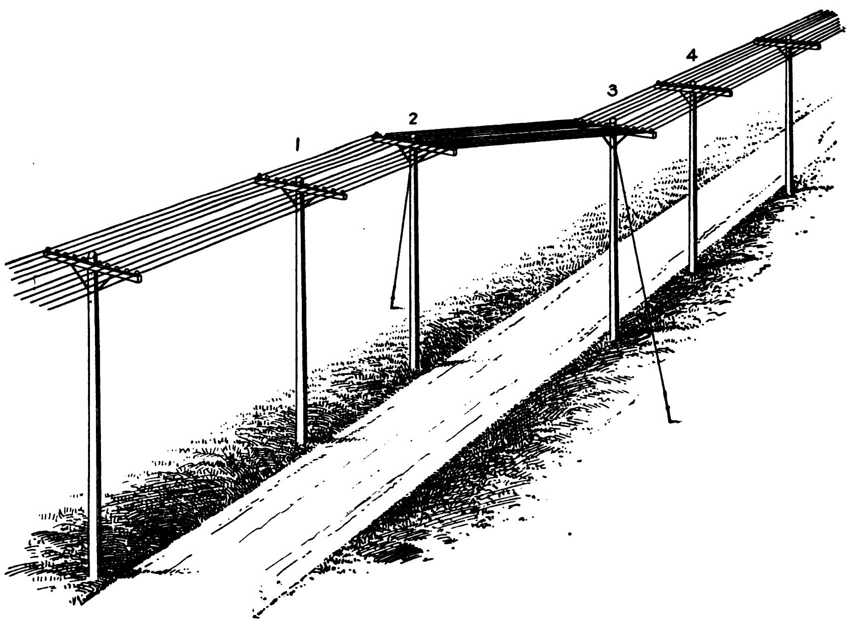

Fig. 5–8.—AERIAL LINE CONSTRUCTION, GUYING AT ROAD CROSSING.

Guy stubs shall be not less than 22 inches in circumference.

The timber to be used for pole braces shall be of the same quality as that specified for poles. Braces should be not less than 18 inches in circumference at smaller end.

A bracket line or other line supporting one or two wires will not always require guys or braces except on corner poles where the angle with the straight line approximates 90°, and at road crossings or terminal poles. Where guys are required, it will usually be found that 144 mils diameter iron or steel wire, galvanized, will be sufficiently heavy, used with a small deadman or 6-inch guy anchor. Curves of less than 45° should be provided for by giving the pole the proper rake.

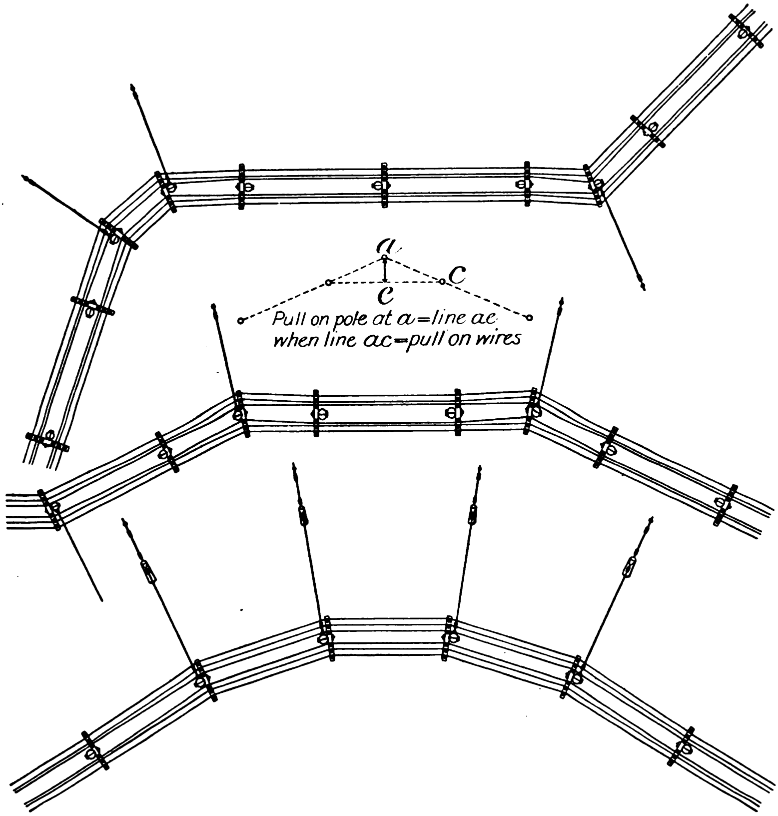

Fig. 5–9.—AERIAL LINE CONSTRUCTION, GUYING AT CURVES.

For lines carrying six or more wires all poles which are out of line should be guyed. For a lead of six or less wires, standard guy wire, one-fourth or five-sixteenths inch diameter, will usually be found sufficient, used with a 6 or 8 inch guy anchor or ordinary deadman.

On lines carrying 10 or more wires guy wire should be not less than three-eighths inch, with not less than one 8-inch guy anchor or usual deadman.

Wherever a line makes a right angle corner with two poles, the poles should be guyed as shown at *A*, figure 5–7. Where it is impossible to place such guys an alternative method shown at *B*, figure 5–7, may be employed, the line wires between poles 1 and 4 being slack, and the strain of line in both directions being sustained by guys placed as indicated in note.

On straight roads where the line crosses from one side of the road to the other corner poles should be guyed as shown in figure 5–8. Terminal poles on 20-wire lines should be head guyed, and if practicable side guyed in both directions. When open-wire lines of 20 wires or more are dead ended in one direction only, the pole adjacent to the terminal pole should be head guyed.

The methods of guying on curves are shown in figure 5–9.

The above figures showing the methods of guying also indicate the sides of the poles on which the cross arms should be placed under varying conditions. In locating anchor guys the distance from the butt of the pole to the eye of the anchor should be not less than one-fifth the length of the pole and, preferably, should be about the length of the pole. A typical "dead man" with anchor is shown in figure 5–10.

The anchor rod shown is of five-eighths inch galvanized steel. The rod passes through the anchor log and is held in place by a nut and square washer, as shown. The size of the anchor log will vary with the depth of the excavation. For an excavation of 5 feet in depth the anchor log will be 5 feet long and 8 inches in diameter. For a shallow excavation a larger and longer anchor log should be used. The anchor log, after being placed in the excavation, should be covered with planking, as shown. If this is not available logs or rock may be used for the same purpose. Guys should be attached to the pole immediately

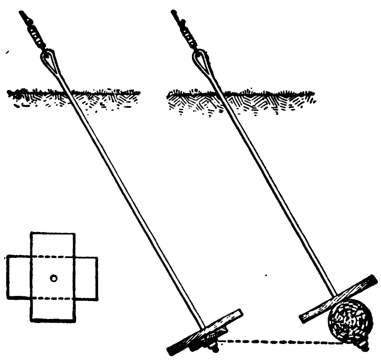

Fig. 5–10.—AERIAL LINE CONSTRUCTION, DEADMAN AND ANCHOR ROD.

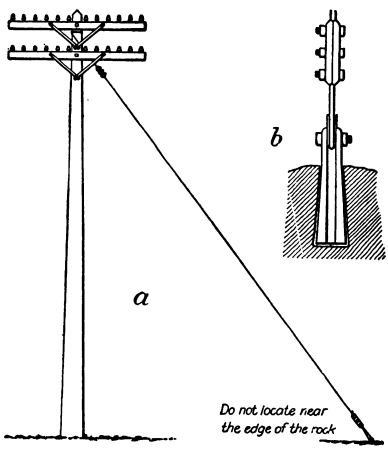

Fig. 5–11.—AERIAL LINE CONSTRUCTION: METHOD OF GUYING TO ROCK.

below the upper cross arm or the lower bracket, as shown at *a*, figure 5–11. Where 144 mils diameter or other solid wire is used for guys, the wire should be fastened at either end by wrapping the end about the main wire. Where stranded wire is used, the guys should be fastened at each end by means of an approved form of guy clamp, either two or three bolt. A thimble should be used for attaching the guy to the guy bolt or guy rod. The end of the wire should be attached to the stub or pole and wrapped twice about this, the wrapping being held in place on the pole or stub by a staple, lag screw, or heavy nail.

The attachment of guys to tree trunks is permissible, although when this is resorted to specific permission for using the trees must invariably be obtained. In attaching guys to tree trunks, a hole slightly larger than the five-eighths inch guy rod should be drilled directly through center of tree, a short distance from ground. This distance is dependent upon the size of tree, as with a comparatively small tree the swaying of the tree is apt to loosen line if guy is attached a considerable distance from ground. Square washer and nut should be placed on guy rod, and by means of a ball hammer the rod should be headed over in order that nut can not readily be removed. The guy is attached to eye of guy rod in the usual manner.

When it is necessary to attach a guy to solid rock, the method shown at *b* of figure 5–11 should be followed.

It may be found necessary in some cases to substitute pole braces for the guys shown, although the former are not considered as desirable a reinforcement as

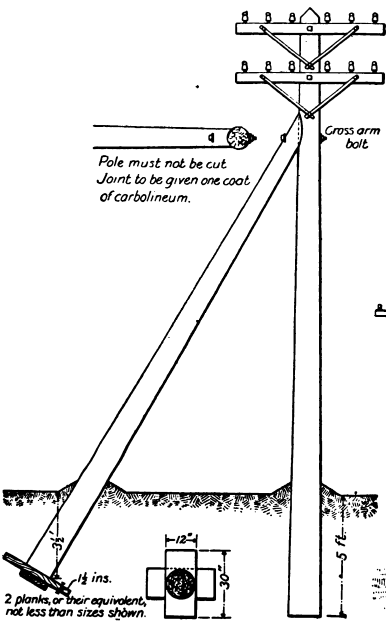

Fig. 5–12.—AERIAL LINE CONSTRUCTION, POLE BRACE.

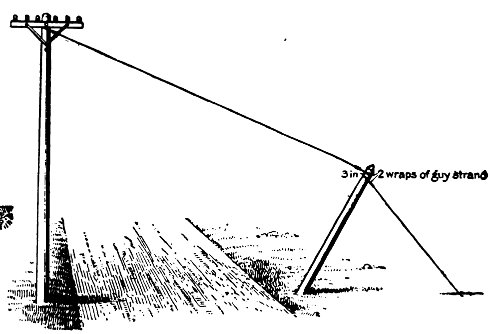

Fig. 5–13.—AERIAL LINE CONSTRUCTION, GUYING ACROSS ROAD.

guys. Where pole braces are used, the butt of the brace shall be set at least 3½ feet in the ground, on a firm support of planking, stone, or similar material. An approved method of installing pole braces is shown in figure 5–12.

Where it is necessary to raise guys over roadways or to clear obstacles, guy stubs should be employed, as shown in figure 5–13. The stubs should have a top circumference of not less than 18 inches and should be set in the ground to a depth of at least 5 feet, and should lean away from the pole to which the guy is attached.

In general practice two turns of the guy should be made around each pole, one end of the block attached to the body of the messenger or guy and the other attached to the free end, the fall of the blocks passing back and down to the ground over a convenient stub or snatch block. All anchor guys, head guys, and corners should be pulled with two sets of guying blocks, one being used as a luff for the other set.

GUARD WIRES.

Where guard wires are necessary to protect wires from other wires crossing above, they will be put up as described and illustrated below. Referring to figure 5–14, poles 1 and 4 should be framed so as to leave 1 foot of the pole above the top arm. Poles 2 and 3 should be framed in the regular way, with pin in ends of arms, as shown in sketch. The upper wires represent guard wires, which should be of 144 mils diameter galvanized iron where the crossing is

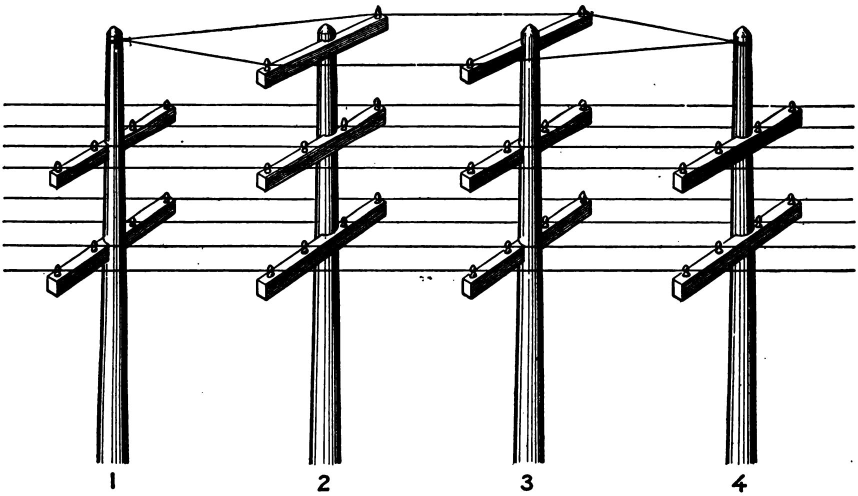

Fig. 5–14.—AERIAL LINE CONSTRUCTION, GUARD WIRES.

under low-tension wires. Where the crossing is under high-tension wires, standard guy wire or 229 mils diameter wire should be used as guards.

The guard wires terminate on the top of poles 1 and 4, where heavy porcelain knobs or other circuit breaks should be used when the crossing is under high-tension wires. The straight lines show the working wires as they will appear after guard arms and wires are up.

Where crossing under a heavy lead and heavy guard wires are used, guy wires should be run from the top of poles 1 and 4 to a point 8 or more feet from the butt of the next pole to hold the strain of the guard wires.

INSULATORS.

The standard insulator is the pony-porcelain insulator, double groove. Special cases may require the use of a heavier insulator, but in general the above type will be found suitable.

STRINGING WIRE.

After the pole line has been completed, with all guys, anchors, etc., in place, the stringing of the wire should next be taken up. The working party for this purpose will comprise a foreman; a sufficient number of linemen, varying from two to six; one or two groundmen; and such means of transportation as may be necessary. The linemen are equipped with tools for splicing wire and for attaching it to the insulators and must be men who are able to climb poles and work to advantage thereon.

No. 14 B. W. gauge (81 mils diameter) galvanized-iron wire is sometimes furnished for temporary local battery telephone systems. For common battery telephone work No. 12 B. & S. gauge (81 mils diameter) hard-drawn bare copper wire is furnished. This wire is supplied in coils of 1 mile and should be handled with extreme care to avoid bruising or scratching its surface. Any scratch or bruise made should be cut from the wire before it is installed. Splices should invariably be made with copper splicing sleeves furnished especially for this purpose. Line splices should not be soldered.

All line wire shall be strung from pay-out reels in such manner that it shall be free from kinks or twists. For copper wire, Buffalo grips should be used so that it will not be injured. For galvanized-iron wire, either a Buffalo grip or other form of clamp may be used. Wires are to be strung with a uniform sag, so that all the wires on a cross arm shall be even. (See table below.) For short iron-wire lines, and for copper wire, joints need not be soldered. Iron wire should be tied in with soft iron wire of the same size as the line wire. Copper wire should be tied in with pieces of soft copper wire of the same size as the line wire.

Sag of aerial-line wires.

Temperature.	60-foot span.	80-foot span.	100-foot span.	120-foot span.	140-foot span.	160-foot span.	180-foot span.	200-foot span.
° *F.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
− 30	0.6	1.1	1.9	2.8	3.9	5.1	6.5	8.0
− 10	.8	1.5	2.3	3.3	4.5	5.8	7.4	9.0
+ 10	1.0	1.7	2.6	3.8	5.1	6.6	8.0	10.4
+ 30	1.1	2.0	3.1	4.5	6.1	7.9	9.4	12.0
+ 60	1.6	2.7	4.2	5.9	7.8	10.0	12.0	15.4
+ 80	2.1	3.7	5.6	7.9	10.2	12.7	14.9	19.0
+100	2.9	5.0	7.2	9.9	12.6	15.6	18.0	22.4

Having provided the working force with the necessary tools, a coil of wire is placed on a pay-out reel, the binding wires removed, and the outer end of the wire attached at the starting point. The wire on the reel is then carried along as near the line of poles as possible, so that the wire will run out straight and in a convenient position for carrying up. When a sufficient amount of wire has been run out it is carried up by the linemen and placed in a loose tie on the insulator. The groundmen then pull the wire up to the proper tension, after which the tying in is completed.

The method just described of paying out wire is applicable for construction of new line where there is no danger of interfering with traffic or having the wire injured. When additional wires to an existing aerial line are run, it is usually advisable to have the pay-out reel stationary. In such cases the wire or wires (a number can be pulled at one time, a pay-out reel being supplied for each line) are attached to a long lead rope which is carried up and passed over the cross arms. The latter method is also applicable in the construction of new line when it is imprudent to have wire lie on the ground.

Where more than one wire is pulled by means of the latter method the wires should be made fast a short distance apart to a light, strong piece of wood termed a " spreader " and the lead or pulling rope made fast to the center of the spreader.

HANDLING HARD-DRAWN COPPER WIRE.

While hard-drawn copper wire possesses hardness and strength for all practicable purposes, it will not stand without injury the rough handling to which iron wire is ordinarily subjected.

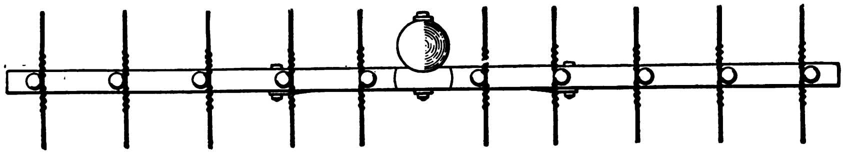

Fig. 5–15.—AERIAL LINE CONSTRUCTION, WIRES ON INSULATORS.

Every coil should be examined before the outside cover is removed. In case the covering is torn, the wire itself should be carefully inspected to see that it has not been cut or bruised. In case the wire is found to have been injured, the injured portion should be cut out before using.

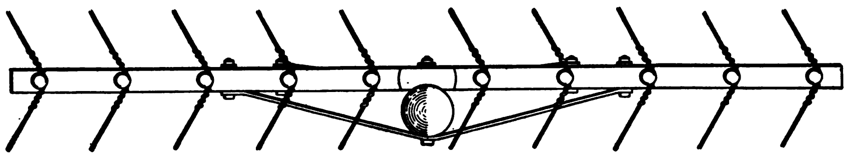

Fig. 5–16.—AERIAL LINE CONSTRUCTION, WIRES ON INSULATORS, CORNER POLE.

Copper wire should never be thrown from an appreciable height.

While unreeling, great care must be taken to avoid twists and kinks. Whereever either is found, it must be cut out and a good splice made. This applies also to splits, bruises, or indentations of any kind.

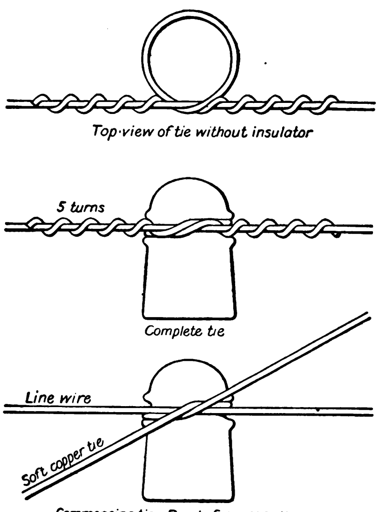

Fig. 5-17.—AERIAL LINE CONSTRUCTION, TYING H. D. COPPER WIRE TO INSULATORS.

In tying the wire, care must be used not to tie it so tight as to cramp or kink it between the tie wire and the glass. Hard-drawn copper wire must not be tied with any wire other than soft copper.

When once hard-drawn copper wire is carefully put in place without kinks, indentations, or bruises it will stand changes of temperature, sleet storms, etc., practically as well as iron or steel wire of much lower conductivity.

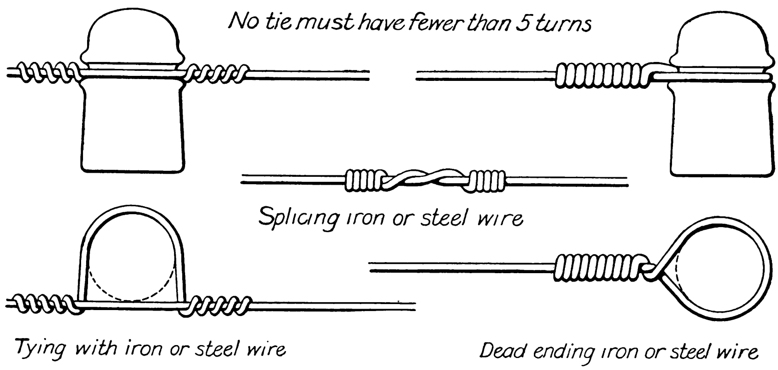

Fig. 5–18.—AERIAL LINE CONSTRUCTION, TYING AND SPLICING IRON AND STEEL WIRE.

For straight lines, the wires should be placed on the insulators as shown in figure 5–15. It will be noted that all wires are on the pole side of the insulators, except the middle pair, which is placed on the outer side to provide a greater separation. On corner poles all wires should be placed as shown in figure 5–16.

The approved methods of tying the line wires to the insulators are shown in figures 5–17 and 5–18. It will be noted that the methods for iron and copper wires are different. Soft copper ties should be used for copper and soft iron for iron or steel line. Care should be taken not to injure the wire in tying to insulator, and at the same time a secure fastening should be made.

TRANSPOSITION.

It may be found necessary in some cases to transpose a metallic circuit to prevent cross talk between telephone lines or interference from foreign circuits. Where it is necessary to transpose, the method shown in figure 5–19 should be followed.

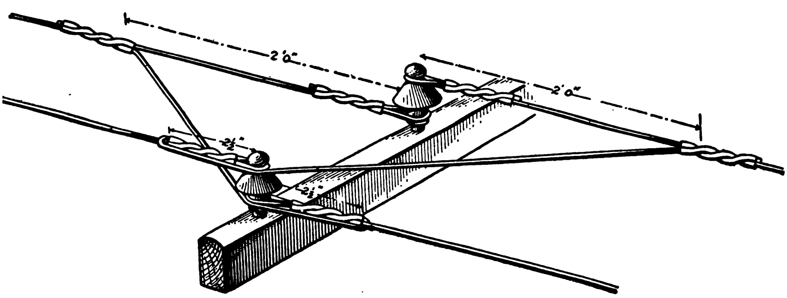

Fig. 5–19.—AERIAL LINE CONSTRUCTION, LINE TRANSPOSITION.

In making a transposition the use of corner poles or curves should be avoided as far as practicable.

On long lines it will be found convenient to have a test station where the line may be opened and tested both ways for the location of trouble. A form of test station made on a two-piece transposition insulator is shown in figure 5–20.

RIVER CROSSINGS.

When navigable streams cross the route of the line, it is usually the better plan to use submarine cables, except where they are liable to be washed out by freshets; but if this method be for any reason impracticable, elevated supports must be used and the wire suspended above danger from passing vessels. Natural supports, such as trees well rooted in safe positions, if such can be found of sufficient height, may be used, or masts erected and securely stayed with wire or wire-rope guys. If the span between supports be not more than 1,500 feet, the line wire can be used, care being taken to select the best, and a

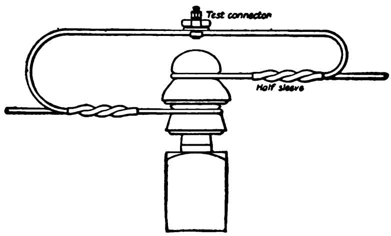

Fig. 5–20.—AERIAL LINE CONSTRUCTION, TEST STATION.

length without joints or with joints very carefully made. For greater spans a steel wire (or compound wire having a steel core) is necessary, with which spans upward of 2,000 feet can be made, provided the points of support are high enough to allow of a proportionately deep sag to the wire. Extreme care must be given to such crossings and too great strain avoided. For further information and illustrations relative to river crossings, the reader is referred to the subject of "Long Spans" appearing later in this chapter.

LINE CONSTRUCTION TOOLS AND MATERIAL.

For complete lists of line-construction tools and line-construction material, see chapter 8 of this manual. In submitting requisition these lists should be followed as closely as possible, as the items listed therein are usually in stock at supply depots or may be purchased in open market without appreciable delay.

Pole lines for aerial cable should be built as specified for open wire lines in the preceding part of this chapter. The setting and guying of poles should be given special attention, and at corners and terminal poles it is of first importance that the poles hold their original positions rigidly if the cable is to remain in a neat and workmanlike manner after erection. After the erection

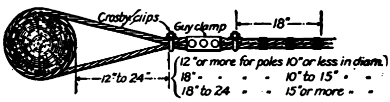

Fig. 5–21.—AERIAL LINE CONSTRUCTION, DEAD ENDING MESSENGER.

of the pole line has been completed, with all guys, anchors, etc., installed, the messenger wire should be erected. Not smaller than three-eighths inch strand should be used for messenger. The same size of strand that is used for carrying the cable should also be used for guys. The properties of various sizes of strand are given in the following table:

Breaking strain.	Diameter of strand in inches.	Lay in inches.	Elongation of each wire in 10 inches.		Weight per 100 feet.
			Maximum.	Average.	
Pounds.			*Per cent.*	*Per cent.*	*Pounds.*
11,000	1/2	4½	13	11	52
9,000	7/16	4½	13	11	42
6,800	3/8	4	13	11	30
4,860	5/16	3½	12	9	22
3,050	1/4	3	12	9	13
2,000	3/16	3	10	9	8

An approved method of dead ending messenger wire is shown in figure 5–21. It is desirable to have the messenger installed without splice, also to continue it past last pole without change of level, to a guy stub. The terminal pole and stub are then guyed, as shown in figure 5–22.

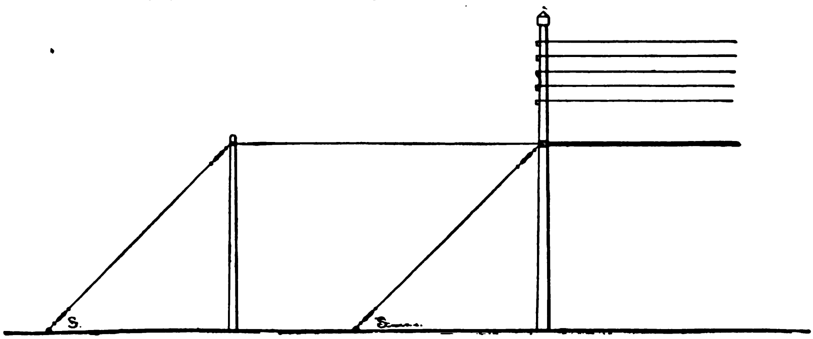

Fig. 5–22.—AERIAL LINE CONSTRUCTION, DEAD ENDING MESSENGER, GUYING.

Whenever possible, the anchor for the stub should be placed at a distance from the stub equal to the distance from the guy to the ground level. This will give the anchor guys an angle of about 45 degrees. On all poles or stubs where

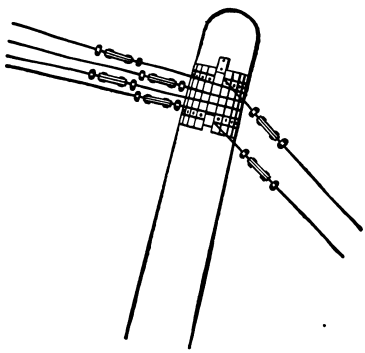

Fig. 5–23.—AERIAL LINE CONSTRUCTION, SHIMS AND CLAMPS.

extra heavy steel strand or messenger dead ends or extra heavy guys are installed, metal guy shims should be used as shown in figure 5–23.

Thimbles should be used in the eyes of all anchor rods.

Splicing of messenger should be avoided if possible but when necessary may be done as follows: Two ends of the messenger should be lapped about 6 feet. Three 3-bolt clamps should be put on in the center lapping sections, spacing them so that they touch end to end. At each end of the outside of the three clamps one Crosby clip should be placed 1½ inches from the three clamps with the yoke over the short end of the messenger and the bearing plate on the main

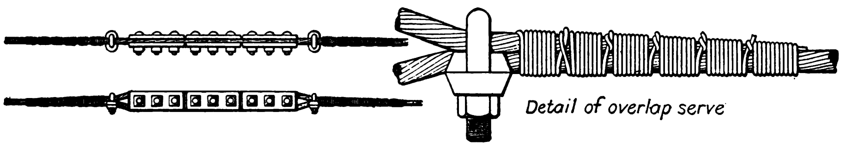

Fig. 5–24.—AERIAL LINE CONSTRUCTION, SPLICING MESSENGER.

messenger. The end should be served up with overlapping sections of serving as shown. The completed splice is shown in figure 5–24.

Various methods of attaching the messenger to poles are used. Messenger supports attached with two lag bolts placed as shown in figure 5–25 are most commonly used.

A messenger support as shown in figure 5–26 attached by a through bolt may also be used. In ordering supports of either pattern the size of the strand with which they are to be used should be stated. Bolts for attaching are not furnished as a part of the support and should be ordered separately. The messenger supports should be installed before the strand is run out. To erect strand, place the reel on an axle supported by two jacks, if available, and run off the required length along the line as near the poles as possible. This is then carried up the pole by the linemen, the hangers being already in place. One end is then dead ended, as shown in figure 5–21. At the other end a pair of 6-inch triple blocks should be hung on the guy stub terminating the pole line, and slack pulled out of the messenger and carried around the pole loosely and fastened with a clamp for safety. Next, a 10-inch snatch block is hung just below the guy shims on the side of the pole parallel with the street. It should be secured to the pole with the equivalent of four turns of inch rope. A piece of three-eighths inch strand measuring 100 feet or more should be attached to the messenger by means of Crosby clips or three-bolt guy clamps in a permanent manner, approximately 15 feet from the stub. The piece of strand attached to the

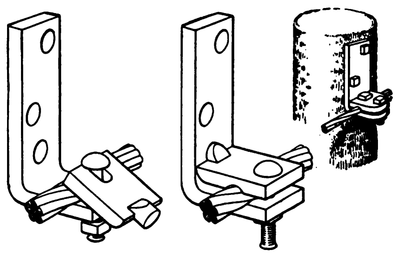

Fig. 5–25.—AERIAL LINE CONSTRUCTION, MESSENGER SUPPORTS.

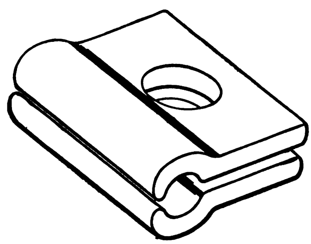

Fig. 5–26.—AERIAL LINE CONSTRUCTION, MESSENGER SUPPORT, THROUGH-BOLT TYPE.

messenger should now be carried through the snatch block to the butt of the next pole, a tree or other sufficiently firm object. A pair of 10-inch triple-sheave hoisting blocks should be made fast to this pole or other object and lashed with two turns of inch rope or its equivalent. These blocks should be attached to the strand leading over the snatch block with the blocks spread at least 30 feet. A pair of luff blocks should be attached to the fall of the main blocks by a stopper hitch, allowing the main fall to be snubbed around the nearest solid support. The slack should now be pulled up by the fall of the luff blocks, using for this purpose a horse or force of ground men. The arrangement of block and tackle described is shown in figure 5–27.

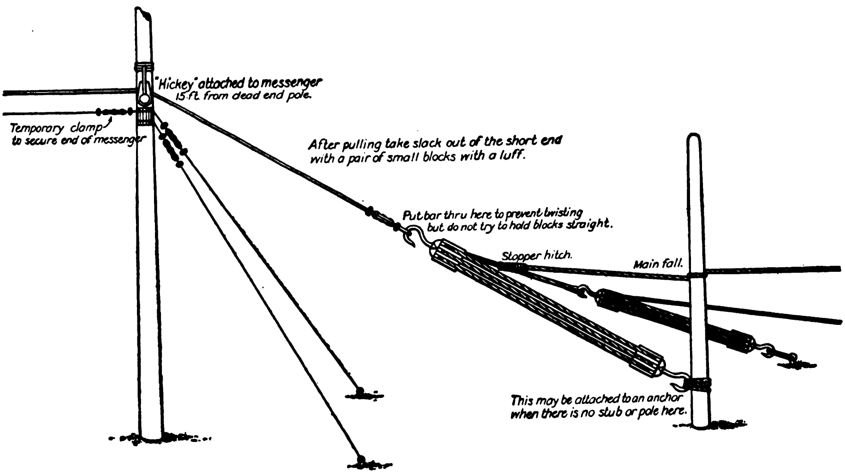

Fig. 5–27.—AERIAL LINE CONSTRUCTION, ARRANGEMENT OF TACKLE.

When the desired tension has been obtained, the main fall should be permanently snubbed and the messenger made fast. This is done by passing the end twice around the pole, the free end hooked to one end of a pair of 6-inch triple blocks. The other end of these blocks should be secured to the main messenger. The fall of these blocks should be carried through a second and smaller snatch block to the ground, where it may be handled with other luffs to take out the slack in the messenger.

When this is done, the messenger is secured by Crosby clip and 3-bolt guy clamp, as shown in figure 5–21. The tension of the main blocks should be eased off gradually and with caution until the dead end of the messenger has taken up the full strain. This having been completed, the messenger supports should be tightened up on each pole.

The method of putting up messenger just described is of general application and will be found suitable for the heaviest strand installed.

The messenger should never turn double corners or change from one side of the street to the other by being pulled around the corner. On double corners, messenger and cable should make the square turn, as shown in figure 5–28. On changing sides of the street the messenger should terminate at last pole, beginning again on the opposite side of the street, both corner poles being side guyed as well as head guyed.

When the cable is in place on the messenger the sag in inches should not exceed the limits of the following table:

Temperature.	100-foot span.	120-foot span.	140-foot span.	160-foot span.	180-foot span.	200-foot span.
°*F.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
−30	12	17⅜	23½	30¾	39	48
0	12¼	17½	24	31½	40	49½
+30	12¾	18⅝	25½	33⅝	42⅝	52⅞
60	13½	20	27⅜	36	45⅞	56⅝
90	15¼	22	30	39⅜	50⅛	63½
120	18	25½	34⅛	42⅞	55	67¼

When pulling the strand taut allowance should be made for the weight of the cable, which will increase the sag, and the strand should be made correspond-

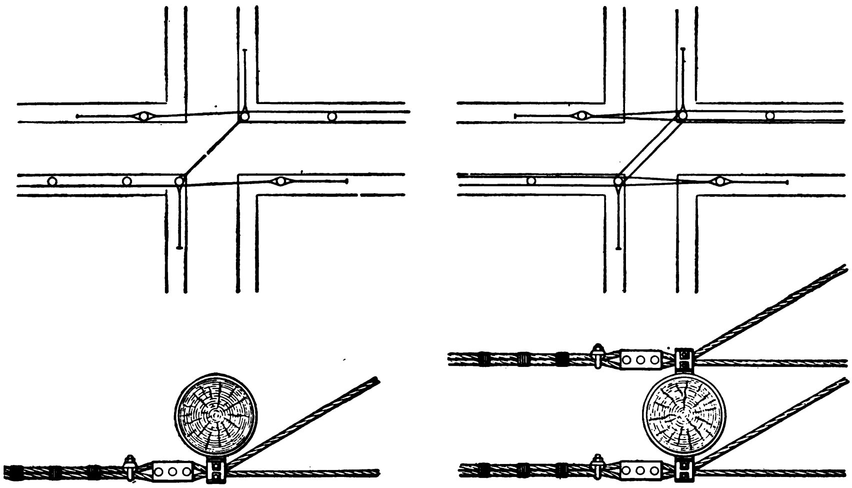

Fig. 5–28.—AERIAL LINE CONSTRUCTION, CHANGING DIRECTION OF MESSENGER.

ingly taut. It will hardly be possible to place the strand under too great a tension. As the strain is applied, careful watch should be kept for loosening guys or anchors, buckling of poles, etc. The blocks should be attached to the messenger wire by means of steel comealongs rather than buffalo grips. They may be attached to the pole or anchorage by the use of a sling of messenger strand or manila rope.

GUYS.

If a single messenger wire is used on a universal hanger, the pole guys should be placed above and as close to the messenger as posible. The guys should be wrapped twice about the pole or guy stub, and should be held with guy clamps.

Where several guys are placed on one pole they should be assembled as closely as possible, but should not overlap or bind each other. When head guys, storm guys, strand or other guys are fastened to the butt of the pole, they should be as close to the ground as practicable, but usually not nearer than 8 feet. Guy stubs should not be left with any side strain whatever. This can be prevented in two ways—by side guying the stub itself or by bringing the anchor rods, stub, and point of strain in line.

Cable messengers should be carried at the lowest level permitted by existing conditions, such as other wires, cables, roadways, etc. The height of the main-cable lead should be adjusted, if possible, to meet the requirements of the branch or cross lead. If the level of the cable messenger is to be changed, it should not be dropped abruptly, but should be carefully graded to meet the requirements.

In serving dead ends of messenger sufficient length should be left in the messenger or guy to pass twice around the pole, to permit of the proper distance between the end of the clamp and pole, and to allow a standard length of 18 inches from the clamp to the free end of the strand. This free end should be carefully tightened and served to main messenger with wrapping of 81 mils diameter iron wire. Where several messengers or guys dead end on the same pole the ends and serving should be lined up.

If after the slack has been pulled out of a messenger it appears that the grade might have been better, it should be considered of sufficient importance to raise or lower the support or supports necessary to bring this about. If the conditions are favorable, cable supports may be placed on the poles by tape-line measure from the ground to determine the height. If, however, the ground is uneven or the conditions are otherwise unfavorable small pieces of lath or equivalent may be tacked on the pole and raised and lowered until a satisfactory grade is secured, the messenger supports then being placed at these points. The preliminary pull on the messenger will determine the correctness of the height of the supports.

Cable installed aerially is almost invariably paper insulation plain lead covered.

CABLE HANDLING.

Great care should be exercised in handling cable, in transporting it to the work and in delivery from railroad yards to storehouses. Cable should never be dropped from a platform or wagon, and the reel should never be turned on its end. Reels will usually be marked on the end with a heavy arrow showing the direction in which they should be rolled. The loading or unloading of reels should be under the supervision of a responsible party who understands the handling of cable.

HANGING CABLE.

The messenger having been prepared for the cable, galvanized-iron rings, which are used in the latest approved method of suspending cable, are clamped tightly to messenger, spacing them 15 to 18 inches apart. The reel of cable should be placed approximately one span from the beginning of the run and supported on cable-reel jacks. A temporary leading-up guy equipped with rollers should be placed in position. A drag line for pulling the cable should be brought through the rings from the distant end of the run and attached to the cable by suitable means, such as a cable grip. The cable may then be pulled through the rings by means of a team of horses, winch, or a force of groundmen. It may be necessary to arrange the galvanized-iron rings after cable has been pulled, as one or more of the rings are apt to slip out of place along messenger during process of pulling cable.

When marline hangers are used they are made fast to cable as it leaves the reel by means of the marline and are hooked to messenger by means of galvanized-iron hook which forms a part of the hanger. When the cable is pulled the hooks slide along the messenger. It is necessary to unhook from messenger at each pole and rehook on other side. For this reason all hangers are not

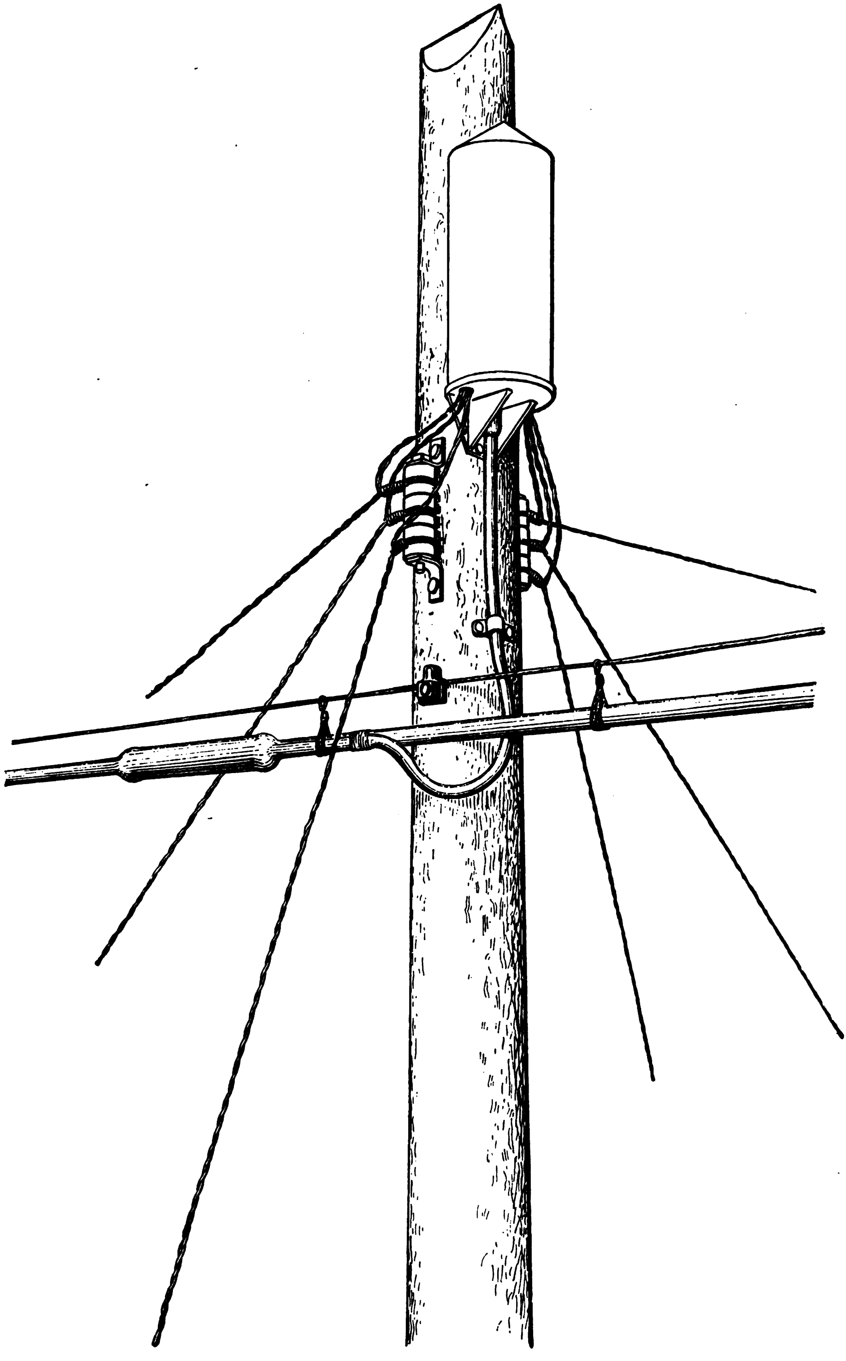

Fig. 5-29.—AERIAL LINE CONSTRUCTION, INSTALLATION OF FUSED CAN TERMINAL.

hooked until the pulling of stretch is nearing completion or is completed. When the pulling is completed all hangers are spaced equidistant and hooked to messenger.

PROTECTION OF CABLE.

Where cable is liable to come into contact with wires, tree limbs, guys, or other objects which will injure the lead sheath, a guard of wooden strips should be put on and lashed with marline. Pump log split lengthwise is sometimes used for this purpose.

CABLE-BOX GROUND.

Arrester ground for cable terminal poles should be carried straight down the pole, without curves, sharp turns, coils, or splices. This ground should consist of a copper wire of suitable size attached to a ground plate, coil of wire, or ground rod buried permanently in moist earth.

LAPPING FOR SPLICING.

Three feet of lapping section is all that is necessary. Whenever necessary to cut a cable, as at the end of a run or otherwise, exposed wires should be driven within the sheath by a pin or bolt and the sheath closed over same and sealed with solder. This is to be considered an absolute rule—to seal all cable ends in this manner immediately after cutting.

The splicing of and making potheads for all types of cable are fully described in chapter 4.

CONNECTIONS TO AERIAL CABLE.

When it is necessary to connect aerial wires to cable it should be through fuses and arresters installed in a can top or cable pole box. A typical method of installing this can terminal is shown in figure 5–29, where drop wires are connected to the cable; the tap taken out of the main cable will never be less than ten pair.

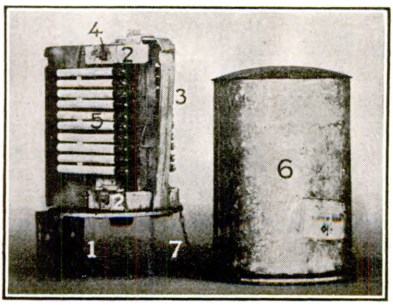

Fig. 5–30.—TERMINAL, CAN, FUSED.

Part No.	Name.	Reference No.
1	Base, metal	1
2	Mounting, porcelain	2
3	Spring holder, complete	3
4	Bolts, clamping	4, 4
5	Fuse, tubular, 5-ampere	5
6	Cover	6
7	Chain for cover	7
8	Fuse springs	....
9	Carbons, pr. and dielectric	....

The conductors of cables are sometimes multipled. That is to say, the same cable pair appears in one or more terminals. The multiple may be made in the splices or by bridging pairs at the binding posts of terminal boxes.

The paper insulation cable should be terminated by a pot head unless it ends in a terminal equipped with a sealing chamber, in which case the standard pot head is not necessary.

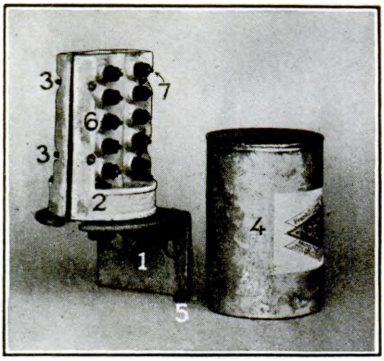

Fig. 5-31.—TERMINAL, CAN, UNFUSED.

Part No.	Name.	Reference No.
1	Base, metal	1
2	Mounting, porcelain	2
3	Bolts, clamping	3
4	Cover	4
5	Chain for cover	5
6	Binding post, hollow, complete	6
7	Binding post, nuts for	7

Terminals of this character are the standard type furnished by the Signal Corps and are supplied in various sizes up to and including 52 pair for the fused terminal and 26 pair for the unfused terminal.

Figure 5-30 shows fused style of these terminals and figure 5-31 shows the unfused. It will be noted that the distinguishing difference is that one style is equipped with fuses and carbon-dielectric protectors and the other is not.

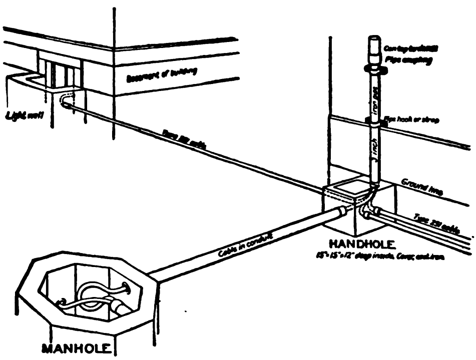

Fig. 5-32.—TERMINAL, CAN, UNFUSED, INSTALLATION OF.

The former or similar ones are invariably used where aerial open lines connect to a cable and the latter are used where lines connected to cables are not exposed to lightning or atmospheric influences, such as in systems employing complete underground distribution, or where connections are made to underground cable which is connected to aerial cable through fuses and carbon-dielectric protectors. Figure 5–32 shows method of installing unfused terminals.

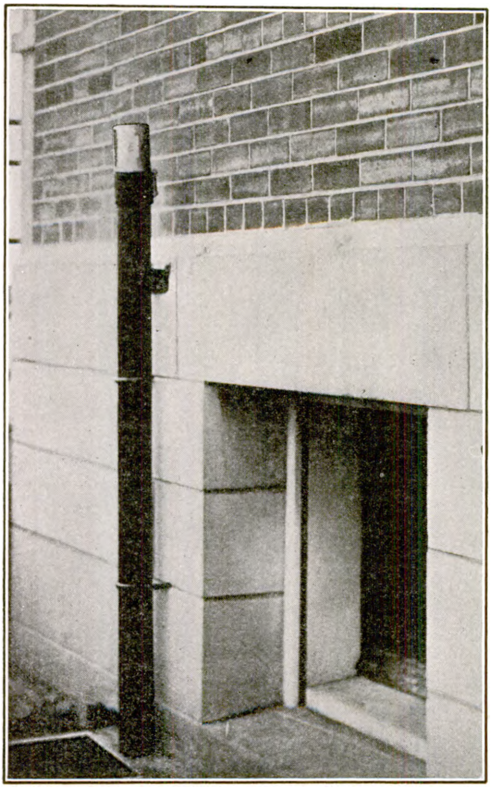

Fig. 5–33.—TERMINAL, CAN, UNFUSED, INSTALLED.

A brief description of aerial-line construction employed in connection with the installation of a post-telephone system at the Front Royal Remount Depot near Front Royal, Va., may be of interest, as conditions to be met were out of the ordinary. The post proper, consisting of the customary administration building, officers' quarters, veterinarian quarters, noncommissioned officers' quarters, barracks, dispensary, and other structures, is equipped with an underground-cable system, the post-telephone switchboard being located in the administration building. Communication to the colt-tenders' quarters is obtained by means of aerial lines connecting with the underground-cable system at the boundary of the post proper. The colt-tenders' quarters are distributed throughout the mountains in various directions from the post proper and some are so located that to construct a pole line to the quarters would be an extremely costly undertaking, when consideration is given to the fact that one substation only would be furnished service by such construction. Where practi-

Fig. 5-34.—AERIAL LINE CONSTRUCTION, FENCE POST LINES.

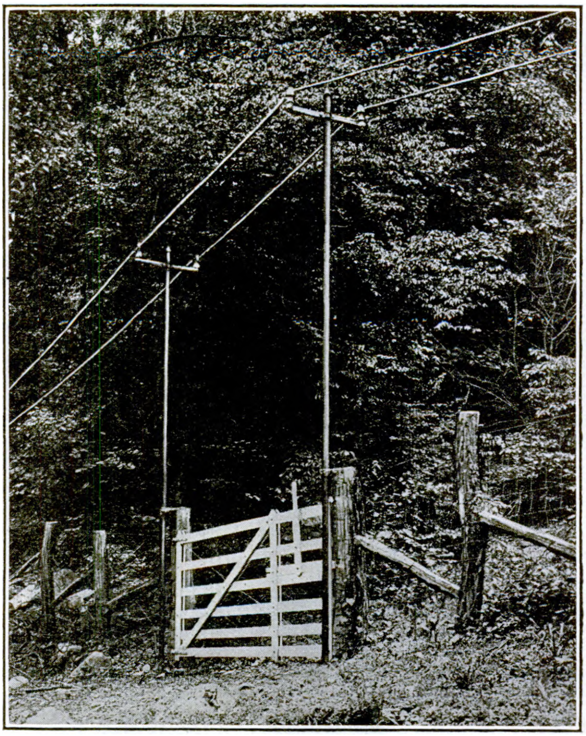

Fig. 5-35.—AERIAL LINE CONSTRUCTION, FENCE POST LINES, GATE CROSSING.

cable the lines were supported by posts of fence lines inclosing the numerous pastures. An ordinary oak bracket was fastened in the usual manner to each side of alternate fence posts and No. 12 B. W. G. iron wire was "tied in" to porcelain insulators on the brackets. In order to obtain greater tensile strength B. B. instead of standard E. B. B. grade of wire was used. Where gates were encountered a Signal Corps telegraph pole with cross-arm was erected beside the gate posts at each side of the gate and the line carried over and above by this means. Figures 5–34 and 5–35 illustrate this construction.

TRIPOD LINES.

In Alaska, where a great many poles have been set in perpetually frozen ground, great trouble has been experienced with the poles lifting or "freezing

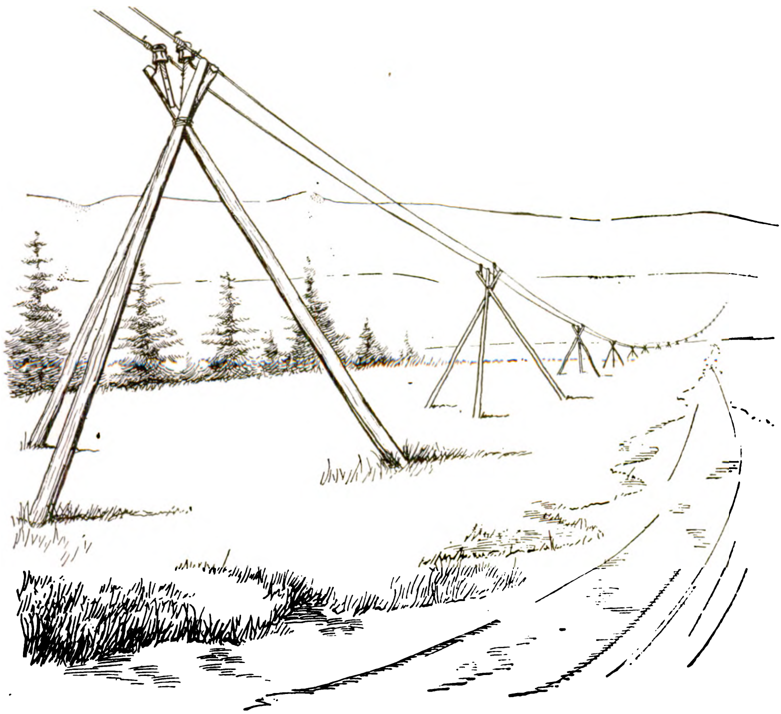

Fig. 5–36.—AERIAL LINE CONSTRUCTION, TRIPOD LINES.

out." A number of methods for preventing such action have been tried, but the concensus of opinion is that any plan which contemplates breaking the surface of the moss or earth is doomed to failure.

Many miles of lines have been constructed in Alaska by the Signal Corps, where poles were set in the ground and in addition were supported by braces in the form of a tripod. While this construction proved more effective than former methods, it was not satisfactory, for, while the braces tended to hold the pole in a vertical position, the "freezing out" was not eliminated in the least, and in some instances assisted in lifting the pole, due to the ground end of the braces moving in toward the pole as it lifted and preventing pole from settling back, if so inclined, during the "break up" or thawing season. This operation, repeated for a few seasons, results in an extremely wobbly and irregular line and necessitates a great amount of traveling and work in a barren country incident to placing the line again in repair.

After experimenting with various methods, the Signal Corps has adopted self-supporting tripods as a means of supporting aerial lines where the conditions are as above stated. Many miles of lines utilizing these tripods have been constructed, and results obtained relative to first cost and maintenance have been highly satisfactory.

Figures 5–36 and 5–37 are reproductions of photographs of this approved tripod construction in Alaska.

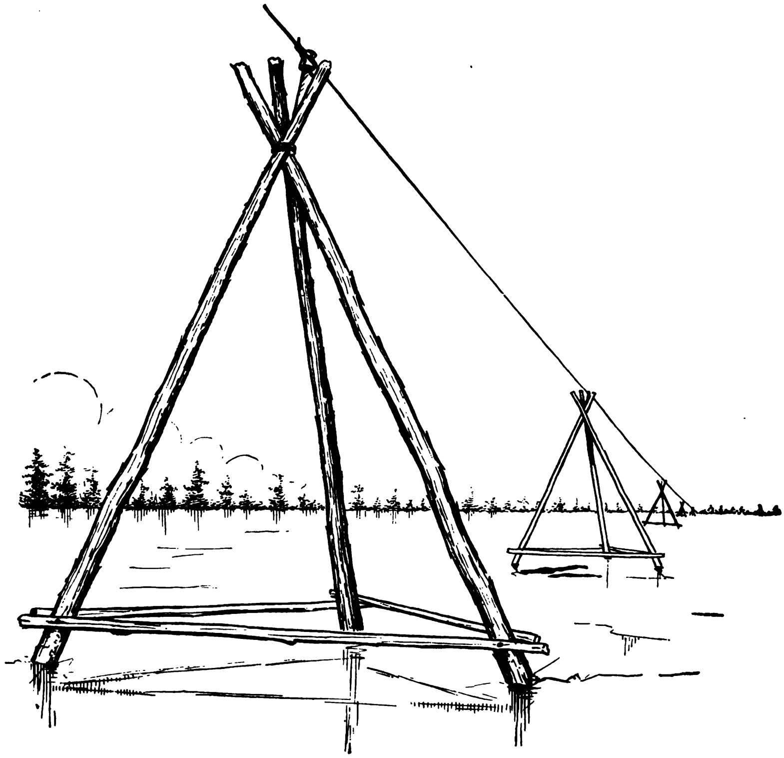

Fig. 5–37.—AERIAL LINE CONSTRUCTION, TRIPOD LINES OVER ICE.

It can readily be seen that these tripods solve the problem of overcoming the disastrous results of poles "freezing out," but in addition to this these tripods present another great advantage which perhaps can be appreciated only by those who have had experience in connection with constructing aerial lines in Alaska.

Ordinarily the digging of the customary holes in the earth for poles is a simple undertaking, but in some places in Alaska the elimination of this part of the work by the self-supporting tripod is, in itself, a feature which greatly reduces the first cost of line construction and makes it possible to undertake the work during weather conditions that otherwise would be considered prohibitive. Under the 10 inches or more of heavy spagnum mosses found in many localities in Alaska the earth thaws but very little even in open country. To dig holes, even late in the summer, is almost equivalent to digging in set cement. Digging bars are soon blunted and must be sent to the tool dresser daily. Attempts to thaw the ground by means of the ordinary prospector's boiler have proved unsatisfactory.

All material used in the construction of a tripod line is comparatively light in weight, and the work involved in construction and maintenance is less than for ordinary pole line. Moving a section to avoid washouts, new roads, or for any cause is more easily accomplished.

Tripod poles can often be procured where the regular-line poles of the dimensions usually required can not be found. Good tripod material is often obtained from dense spruce thickets. The poles for ordinary Alaskan line supporting one or two wires should be 18 feet long, with not less than 3-inch tops, and fairly straight. They should be cut at stump end with an axe, not sawed, as the long, sharp kerf made by chopping in the usual manner is needed for giving the butts of poles a hold in the earth or moss. If cut in the summer the poles should be peeled immediately, as the bark sets in a very few hours, making the removal much more of a task. It is impracticable to peel poles cut in the winter, as there is comparatively little moisture in the wood at that season.

Where a large number of tripod poles are to be cut, it has been found advantageous to prepare racks upon which the poles are placed and peeled as soon as cut. Considerable weight is lost by the poles "drying out," consequently they should not be transported for several days, unless the need for them be urgent.

ERECTING TRIPODS.

After the right of way has been cleared and tripod poles (3 for each tripod) have been delivered to the proper location, a force of six men properly organized proceed to construct the line. The three poles are substantially lashed together with 144-mil diameter galvanized-iron wire, approximately 2½ feet from their small ends, and the tripods raised and aligned in proper position. Oak brackets and insulators are then placed, as shown in figures, and the line wire "tied in" to the insulator in the customary manner. While such construction is best adapted for supporting one or two wires, five or six may be supported with less danger of crosses than there would be with the ordinary bracket line.

As with all line construction, judgment must be exercised in meeting varying conditions when constructing tripod lines, and on curves and corners it may be necessary to guy one or more of the tripods or to equip their bases with three bracing members, as shown in figure 5–37. This figure illustrates the latter method, which was employed in crossing a shallow, frozen lake.

LONG SPANS.

As previously stated in this chapter, where unusually long aerial spans (over 1,500 feet) are necessary a special composition or steel wire should be used. Moderately long spans can be made with galvanized-iron wire. In either case special construction is necessary for resisting the strain, and judgment must be used in determining the manner of insulating the line and anchoring at the two terminals of such a span.

The following illustrations show methods which have been adopted for telegraph lines of the Washington-Alaska military cable and telegraph system in Alaska where it is necessary to cross swift-current rivers and mountain gorges.

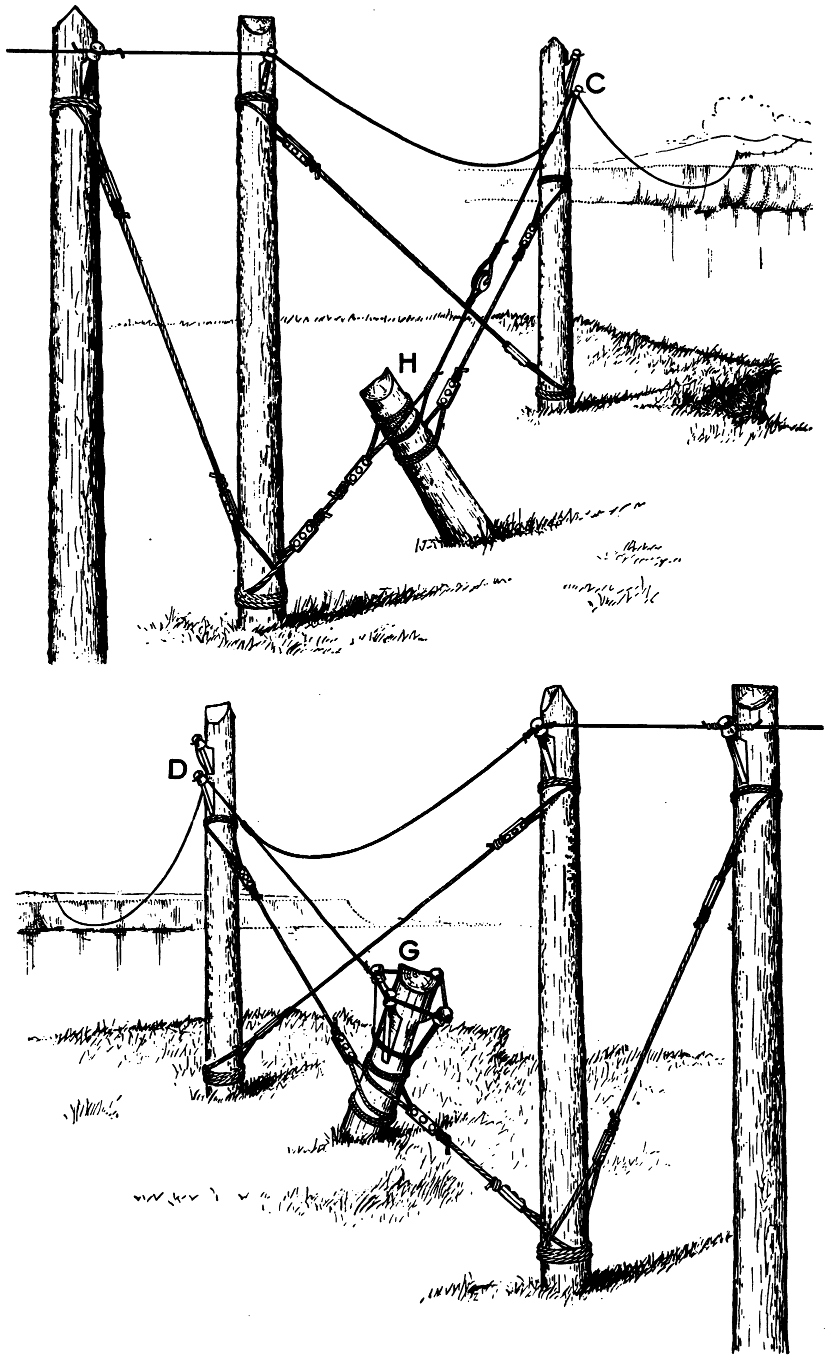

Fig. 5–38.—AERIAL LINE CONSTRUCTION, LONG SPANS, METHODS OF TERMINATING.

It will be noted that no special material except wire, in some instances, is required.

Figure 5–38 shows two methods of providing support for excessive strain of long spans. In some instances both are used, one at each end of the span. The line wire is made fast at *G*, laid in the saddle at *D*, pulled up at saddle at *C*, and made fast at strain insulator attached to *H*. As much sag as practicable should be allowed, as the strain rapidly increases as the wire is pulled taut. The strain of long span is not borne by the land lines, and consequently proper steps should be taken for guying the terminal poles of these lines.

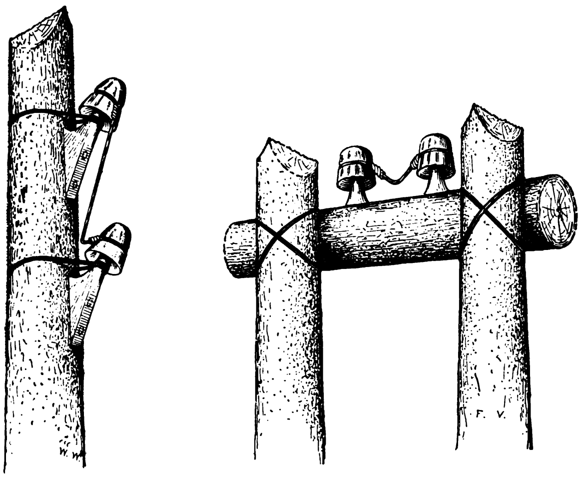

Fig. 5–39.—AERIAL LINE CONSTRUCTION, LONG SPANS, CONSTRUCTION OF SADDLES.

The poles and stubs for this construction should be as short as practicable, but care should be taken to keep the line wires and guy fastenings as far as practicable above snow line, as deep snows will ofttimes break guy wires.

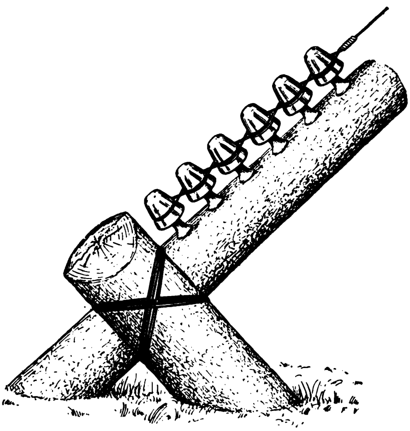

Fig. 5–40.—AERIAL LINE CONSTRUCTION, LONG SPANS, ADDITIONAL METHOD OF TERMINATING.

At crossings on the Yukon River the boat channel is on the bluff side of the river and the water on the opposite shore is usually so shallow that boats can not navigate, consequently short poles and stubs can be conveniently used. At Ruby, Alaska, the bluff is of such height that the pole supporting the saddle is eliminated and the line wire across span is terminated at strain insulators fastened direct to stub shown at *H* and *G* in figure 5–38. While mechanically the strain insulator is best adapted for terminating such lines, from an electrical viewpoint the glass insulator with one or two petticoats properly placed is better than the ordinary strain insulator, as in stormy weather a film of moisture can easily bridge across the strain insulator and thereby cause a heavy leak. Where the latter insulator is used it should be housed by means of a metal funnel, the small part of the funnel fitting snugly to span wire in order to avoid the above-mentioned defect.

Figure 5–39 shows methods of constructing saddles for supporting long span wire. The method shown on left of this illustration is the one employed in figure 5–38.

Figure 5–40 shows an additional method of terminating a long span wire, the wire having passed over a saddle which is not shown in the figure.

Chapter 6.

POST TELEPHONE SYSTEMS.

General Orders, No. 5, dated January 28, 1913, relates to post telephone systems. Extracts of this order are as follows:

1. For administrative purposes the following telephonic communications are authorized at military posts and will be established by the Signal Corps as rapidly as funds become available. Telephones not specified in this order will be installed only upon the approval of the Chief Signal Officer of the Army, and the specific need for each must be stated when application is made for its installation:

Office of the commanding officer	1
Office of the adjutant	1
Office of the quartermaster	2
Office of the quartermaster, additional (when approved in each individual case; to be on same line with other telephone)	1
Office of the Artillery engineer or signal officer	1
Office of the ordnance officer	1
Office of the sergeant major (when approved in each individual case)	1
Each officer's quarters	1
Officers' mess	1
The hospital	1
Each guardhouse	1
The post exchange	1
The pumping station	1
Power plant	1
The corral	1
The quartermaster dock	1
Barracks for each organization, band included	1
Quarters of the senior master electrician, electrician sergeant at Coast Artillery posts, or electricians at interior posts	1
Telegraph office (if located on reservation)	1
Radio station	1
Target range (when approved in each individual case)	1

The telephone switchboard will usually be located in the administration building. Only telephones supplied by the Signal Corps will be connected in any manner to these systems.

In a number of instances temporary post-telephone systems have been installed at military posts. Almost invariably such systems are of local battery type. In some of these systems underground construction has been employed, in others aerial construction, and in others a combination of both.

When a standard system is authorized for a post equipped with a temporary system, provision should be made for utilizing, as far as practicable, the material used in the temporary system.

For information relative to cable system chapter 4 of this manual should be consulted. For information relative to aerial-line construction chapter 5 should be consulted, and in chapter 8 will be found complete enumeration of all material and tools that will be required.

The Signal Corps standard type of post-telephone system is common battery, utilizing underground construction as far as practicable. For telephones at a great distance from post, such as corral, pumping station, and small-arms target range, in some instances, it is impracticable to furnish service underground and aerial construction must be resorted to.

As stated in preceding chapter, where aerial lines are connected to a cable system the cable must invariably be protected by suitable lightning arrester. In addition, each telephone connected to an aerial line must invariably be protected by a suitable lightning arrester.

The lightning arrester protecting a telephone should be located indoors and as near as practicable to entrance of line.

Figure 6–1 shows the Mason lightning arrester, which to date is most commonly used by the Signal Corps, and figure 6–2 shows an arrester which is now being developed for installation in locations that are damp or periodically so.

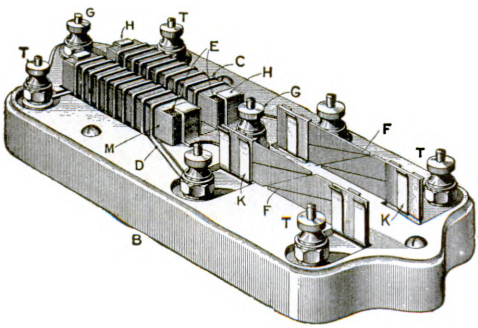

Fig. 6–1.—LIGHTNING ARRESTER, TELEPHONE.

Part No.	Name.	Reference letters.
1	Base, porcelain	B.
2	Choke coil, left (facing choke coil end of arrester)	C.
3	Choke coil, right (facing choke coil end of arrester)	D.
4	Clip, fuse	K.
5	Clip, carbon	H.
6	Carbon rod for choke coil	E.
7	Mica insulators for choke coil	M.
8	Screw, binding, with nuts	T.

Some difficulty has been experienced with the type of arrester shown in figure 6–1 where they have been installed in damp places, as laundries, due to the fact that vapor causes deterioration of coils and temporary low insulation. It is believed that the arrester shown in figure 6–2 is also adapted for installation in the Tropics, where at certain seasons the atmosphere is very humid.

The principle in general upon which these arresters operate is that both sides of the incoming circuit are made to pass very closely to carbon blocks which are connected electrically and directly with the earth. In addition, at this point a choke coil is in series with each line so that a static charge due to lightning coming in on line wires encounters at the same point an easy path to earth and an impediment in the path to instrument the arrester is protecting. A bolt of lightning may be of such magnitude and force that it will divide, following both paths, possibly burning up arrester and instrument, but static charges of sufficient magnitude to injure instrument, which are occasioned by inductive effect of lightning and which frequently occur, are efficiently arrested by these types of lightning arrester.

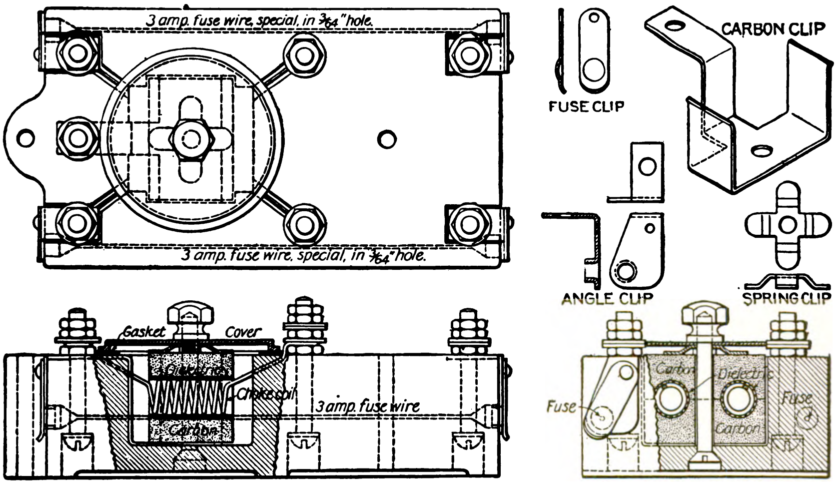

Fig. 6–2.—LIGHTNING ARRESTER, TELEPHONE, MOISTURE-PROOF TYPE.

Part No.	Name.	Reference No.
1	Porcelain block	
2	Cover, brass	
3	Cover, hexagon nut for	
4	Cover, gasket for	
5	Cover, screw for	
6	Binding post, long, with nuts and washer	
7	Binding post, short, with nuts and washer	
8	Choke coil	
9	Carbon blocks	
10	Dielectrics	
11	Carbon clip	
12	Fuse clip	
13	Angle clip	
14	Spring clip	
15	Fuse wire, special, feet	

Lightning arresters for telephones ordinarily have three protective features, viz, fuse, air gap to ground, and impedance coil. The fuse is for opening the circuit whenever excessive current from any cause, such as a cross of power wires, comes in on the telephone line. The fuses supplied should operate for current in excess of one ampere. The air gap is usually a small space between metal or carbon blocks; these are often separated by celluloid or mica, one of these blocks being in contact with the telephone circuit and the other connected directly to ground. Currents of excessive voltage will break down the air gap going directly to ground. The impedance or choke coil acts as a high resistance to high frequency alternating currents which come in on telephone lines, either directly or through induction, and together with the air gap usually lead such currents to ground. Fuses operate too slowly to interrupt lightning or high voltage discharges of any kind.

It is important to note that where there is danger of lines becoming crossed with external circuits, the incoming line should invariably be connected to fuse end of arrester, otherwise an arc to ground would not be stopped by the fuses. Where there is absolutely no danger of lines becoming crossed with external circuits and where considerable trouble is occasioned by the continual opening of fuses due to slight static discharges, the incoming lines may be connected to opposite end of the arrester upon receipt of special permission for such action from the Chief Signal Officer of the Army.

The first step in "laying out" a telephone system for a post is to procure a large, accurately scaled map showing all buildings, present and projective, walks, roadway, contours, and all other objects affecting the location of telephone lines. On this indicate the location of the switchboard and all the telephones to be connected to it. The routes of the various leads of poles and course should now be indicated. These should be determined only after personal inspection of the ground and conference with the post authorities. It is important that the routes as laid down in the first instance should not be changed later, as by so doing the material ordered may be rendered unsuitable, with resulting expense and delay in procuring new supplies. Avoid changing pole line from one side of the street to the other. Avoid trees or other obstacles that would interfere with the line, sharp curves, and electric-power wires. If aerial construction is used, it should be as inconspicuous as possible; other things being equal, run in rear of buildings in preference to front. It may be stated in general that cable should be used where five or more pairs are to be carried in one lead. In laying out cable distribution, the future needs of the service should be provided for as far as possible, and spare pairs made available.

A terminal frame is provided at location of post-telephone switchboard, and all lines to switchboard terminate at this frame, where each is cross connected to a suitable protector.

An exception to this is made in installations where a terminal box is installed in proximity to switchboard, in which case the incoming lines are terminated at terminal strips in this box. In such instances, by means of suitable cabling, the incoming lines are led directly to protectors, and from protectors they are cross connected to cable terminals of frame where the switchboard cables are terminated.

All lines between protector frame and switchboard are contained in switchboard cable, which is fully described later in this chapter.

The type of protector frame varies with size of installation. Where a 50 or 100 line switchboard is installed the protector frame is usually located in a cabinet placed beside the switchboard. This cabinet has the appearance of being a continuation of the switchboard cabinet. In larger installations a frame termed "distributing frame" is installed. This frame is not incased, but consists of angle-iron uprights bolted to angle-iron horizontal members and braces, and may be placed at a distance from wall without being braced to it. With either frame, metal punchings to which are soldered the incoming lines, also a means of cross connecting from these punchings to the protectors, is provided. With the distributing frame large iron rings coated with rubber compound are fastened to the frame at convenient points. These rings are for supporting the cross-connecting wires. Figure 6–3 illustrates the construction and manner of cross connecting the distributing frame.

Various types of protectors are provided, but the object of all is to ground the incoming line in the event of a disruptive current becoming imposed upon the line, thereby obviating damage to switchboard. All protectors are provided with carbons and dielectrics. These carbons and dielectrics consist of two carbon blocks and one dielectric for each side of each circuit. The incoming line is in electrical contract with one of the carbon blocks and the other carbon block is in direct contact with a metal plate which is electrically connected to earth. The dielectric, which consists of mica or celluloid approximately 1 mil in thickness, the other dimensions being same as width and length of carbon block,

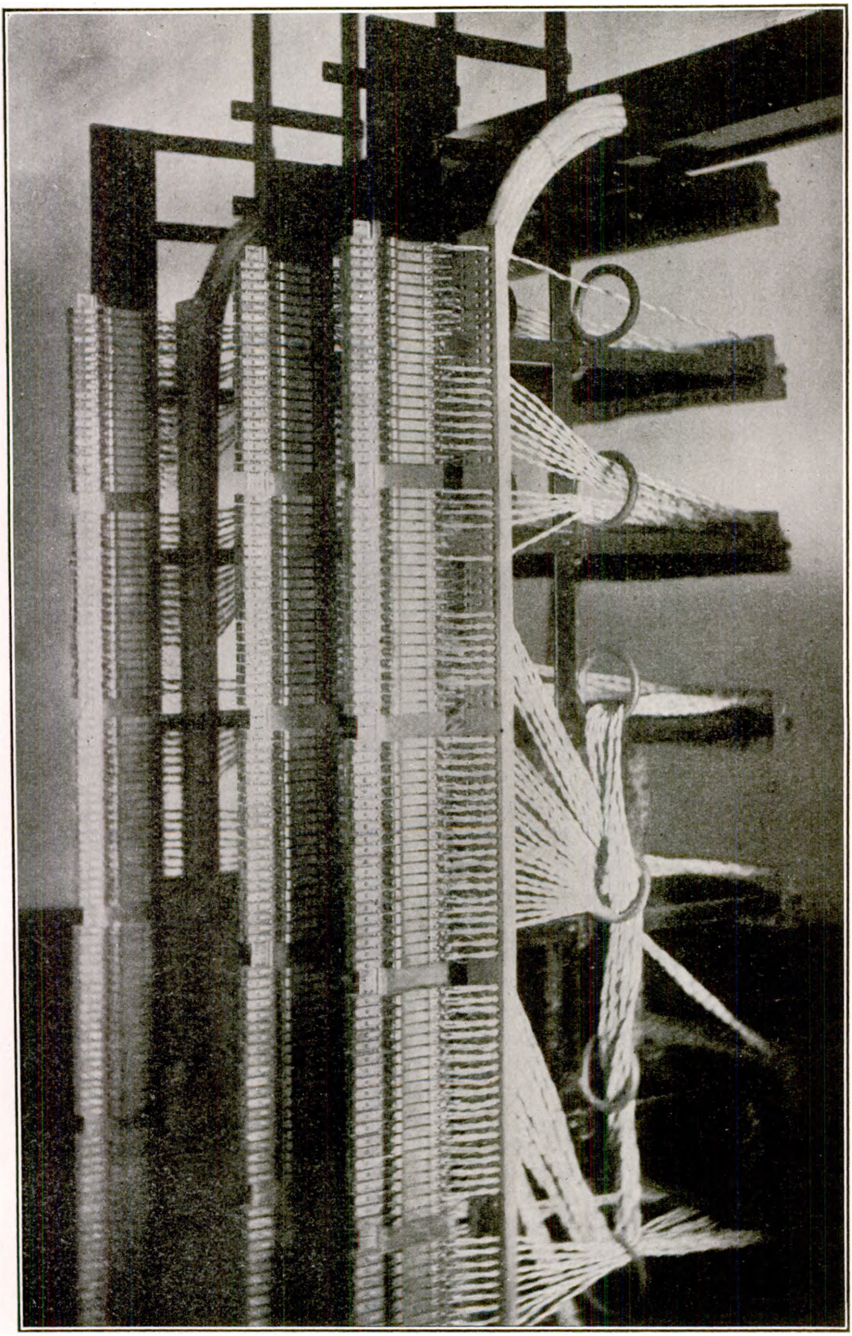

Fig. 6–3.—FRAME, DISTRIBUTING, TELEPHONE SWITCHBOARD.

is placed between the blocks, thereby insulating one from the other. The dielectric is either perforated or has a small U-shaped piece removed so that a dangerous current will have merely a small air gap to break down in order that it will be dissipated in the earth. Static or oscillating currents of high E. M. F. and high potential circuits will be grounded by the part of the protector just described, but a current of comparatively low E. M. F. that would in time burn out windings of switchboard would not be grounded by this means; consequently each protector is also provided with what is termed a "heat coil," with suitable mounting, for arresting the latter currents. These currents are commonly termed "sneak currents."

In one type of these heat coils the passage of a "sneak current" causes the line to be opened and the line side grounded. In another type the line is merely grounded. In either case the operation of the coil is caused by the current heating to a point of "cold flow" solder which normally holds a spring, which is in contact with line, clear of ground plate. The heating is accomplished by means of a winding in some instances and in others by a specially prepared composition. The winding or composition is in series with the incoming line and is so designed that heat is generated when a dangerous current passes through the heat coil. The time element of operation of these coils is inverse to the strength of current.

Currents induced by lightning act too rapidly for fuses or heat coils, and although such currents frequently accomplish unaccountable results the carbon-dielectric part of switchboard protectors almost invariably ground these currents.

The crossing of telephone lines with lighting circuits might complete a circuit through switchboard which would burn out all coils in its path and yet be of such E. M. F. that the carbon-dielectric part of arrester would not act. The heat coil portion of arrester would ground and dissipate such a current before damage to switchboard could result.

COMMON BATTERY POST-TELEPHONE SWITCHBOARDS.

Various types of C. B. telephone switchboards have been installed at Army posts.

The following distinguishing features, which are prominent in identifying the various types, are believed to be worthy of mention:

1. Visual signals for line signal and visual signals for supervisory signal.
2. Visual signals for line signal and lamp signals for supervisory signal.
3. Lamp signals for line signal and lamp signals for supervisory signal.

In most instances the keys are double ringing, although some of the switchboards installed in connection with early installations were equipped with the single ringing type. With the double ringing key the switchboard operator is enabled to ring on either of the two lines which have been connected by means of the switchboard connecting cord. With the single ringing key it is possible to ring on one line only, unless the connecting cords are transposed.

Some of the common battery switchboards purchased by the Signal Corps are designed to operate on a 30-volt circuit while others are designed to operate on a 24-volt circuit. Care should be exercised not to operate the 24-volt signal lamps on 30-volt circuit, as their life is greatly decreased by the excessive voltage.

A description of switchboard equipped with "visual signals for line signals and visual signals for supervisory signals" follows. The circuit of the system where a switchboard of this type is used is shown diagrammatically in figure 6–4. The instruments used in connection with this switchboard conform in wiring and design to well-known commercial standards, and the operation of the switchboard is fully explained hereinafter.

To signal the switchboard (fig. 6–5) it is merely necessary to remove the receiver from the hook, which permits direct current to flow from the common battery through the line signal, one contact of the cut-off jack, the line, the hook, the windings of the induction coil, the transmitter, line, the jack, and back to battery. This causes the line signal to close, attracting the attention of the operator.

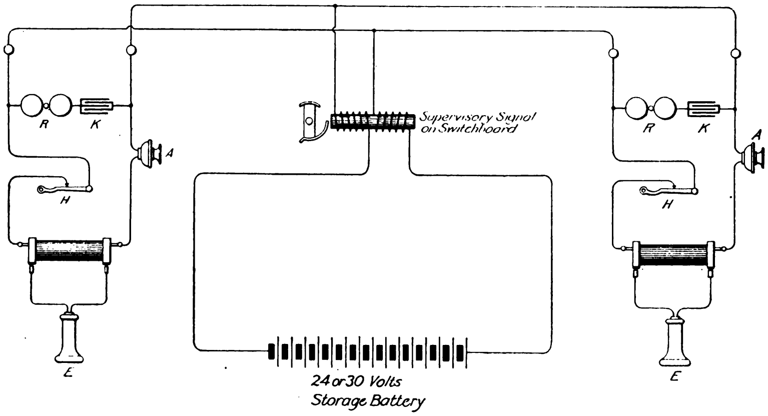

Fig. 6–4.—C. B. TELEPHONE SYSTEM, SIMPLIFIED DIAGRAM OF CIRCUITS.

Referring to figure 6–4, when the switchboard connection is made, disregarding detail of switchboard circuits, current flows from the common battery through the supervisory signal, the lines in parallel to each transmitter, induction coil, hook, line, and back through supervisory signal to battery. The supervisory serves the double purpose of providing the necessary retardation, as previously described, under the composite circuit and of indicating to the operator that the conversation has been completed.

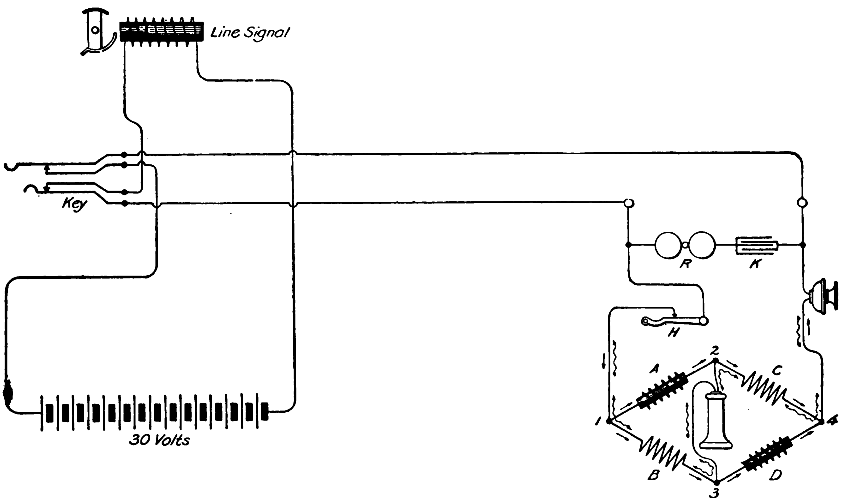

Fig. 6–5.—C. B. TELEPHONE SYSTEM, VISUAL LINE SIGNAL OPERATION.

The instrument circuit of one of the types of common battery telephones used is out of the ordinary and is shown in figure 6–5. It employs the principle of the balanced Wheatstone's bridge to keep the direct current flow from the receiver, while the voice currents, which are alternating in effect, are forced by a combination of retardation and low resistance, located in the arms of the bridge, through the receiver. *A* and *D* are retardation coil windings and *B* and *C* noninductive resistance windings. The bridge is balanced for the direct current flow, indicated by the single-pointed arrows, by making the ohmic resistance of the four arms such that the Wheatstones' bridge equation, $A:B=C:D$, is balanced. There will, then, be no direct current flow between the points 2 and 3, as their potential is the same, and the receiver, which takes the place of the galvanometer in the regular testing bridge, will be entirely free from direct-current action. The bridge, however, is completely out of balance for voice currents, which can not penetrate the high retardations *A* and *D*,

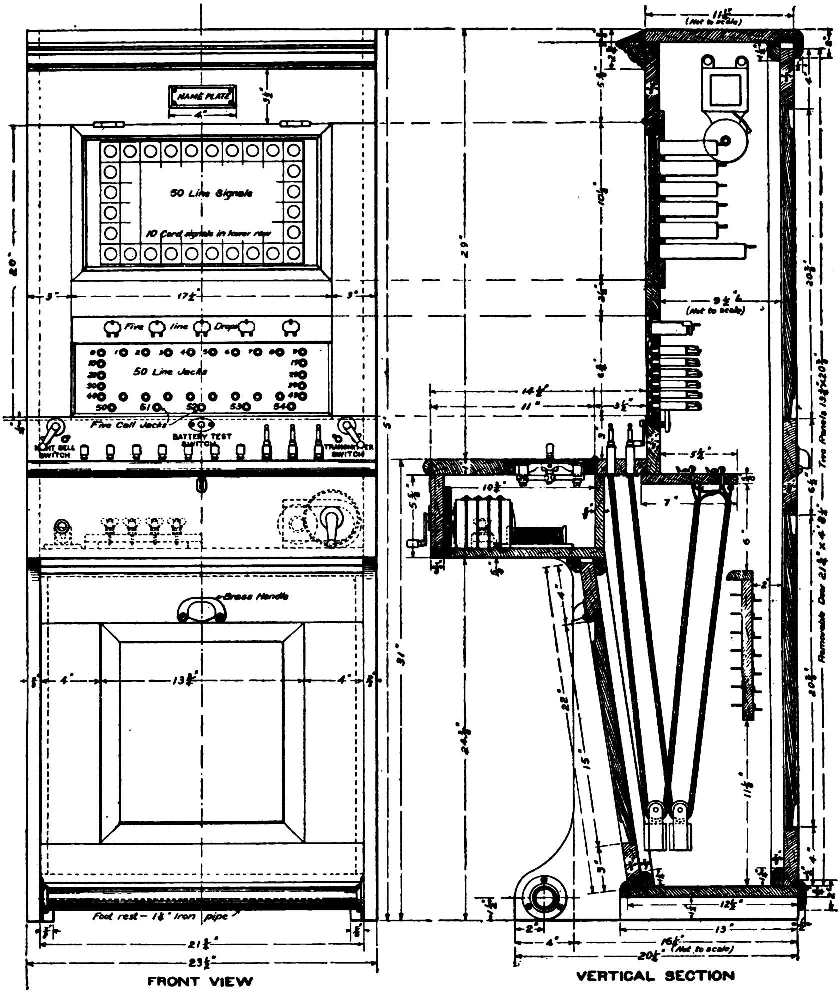

Fig. 6–6.—SWITCHBOARD, TELEPHONE, C. B., 50-LINE, VISUAL.

Part No.	Name.	Reference No.
1	Binding post, lock-nut	
2	Binding post, wing-nut	
3	Bell, night	
4	Bell, night, binding-post nuts	
5	Bell, night, relay	
6	Cable, switchboard, feet	
7	Cord, 4-way, for transmitter and receiver	
8	Cord, switchboard, complete, with terminals	
9	Cord weight	
10	Cord bushing	
11	Cord plug screw	
12	Cord plug shell screw	
13	Cord plug seat with screws	
14	Cord fastener, complete, with screws	
15	Coil, induction	
16	Coil, induction, terminals	
17	Coil, impedance, for operator's circuit	
18	Condenser, 2 m. f	
19	Generator, five-bar	
20	Generator crank	
21	Generator crank handle	
22	Jack, line	
23	Jack, generator call	
24	Key, ringing, complete	
25	Key, ringing, handle	
26	Key, answering, complete	
27	Key, answering, handle for	
28	Line terminal	
29	Receiver, single head	
30	Signal generator call, complete	
31	Signal generator call, drop	
32	Signal generator call, adjusting screw and nut	
33	Signal generator call, mounting screw	
34	Signal generator call, armature mounting screws	
35	Signal generator call, armature pivots	
36	Signal, line, complete	
37	Signal, line, drop	
38	Signal, line, adjusting screw with nut	
39	Signal, line, mounting screw	
40	Signal, line, armature mounting screws	
41	Signal, line, armature pivots	
42	Signal, supervisory, complete	
43	Signal, supervisory, drop	
44	Signal, supervisory, adjusting screw with nut	
45	Signal, supervisory, mounting screw	
46	Signal, supervisory, armature mounting screws	
47	Signal, supervisory, armature pivots	
48	Switch, transmitter	
49	Switch, transmitter, handle	
50	Switch, transmitter, crank with screw	
51	Switch, transmitter, stop pins	
52	Switch, battery test (same as transmitter switch)	
53	Switch, night bell (same as transmitter switch)	
54	Transmitter	

and are thus forced through the receiver and noninductive resistances *B* and *C* in the path indicated by the double-headed arrows. In practice all of the coils of this bridge are wound on one spool and internally connected, so that as far as external appearances or connections are concerned it resembles a standard induction coil. The resistance of the four windings are approximately 20 ohms each for *A* and *B* and 30 ohms each for *C* and *D*. The total resistance of the noninductive windings *B* and *C*, which are in series with the receiver, is therefore only 50 ohms, thus offering no appreciable obstacle to the voice currents. In fact, the receiver is practically, in the line circuit, direct, and receives the maximum available incoming transmission with no distortion or losses.

Common battery switchboards manufactured according to Signal Corps specifications are furnished in three sizes accommodating a maximum of 200 lines, 100 lines, or 50 lines, respectively, the actual equipment in either case depending upon the needs of the installation to which it pertains.

The three sizes are similar in arrangement of parts, in operation, and in wiring. A description of the 50-line size therefore applies to all. This switchboard is shown in figure 6–6, and the protector cabinet mentioned in first part of this chapter is shown in figures 6–7 and 6–8.

In figure 6–8 the Cook self-soldering heat coil and protector is shown, and in figure 6–9 the Western Electric heat coil and protector is shown.

The cabinet of this switchboard is built of oak and provided with an upper and lower rear door, a front panel, a foot rail, and is designed to accommodate all of the apparatus necessary for the operation of the system, except the battery.

In addition to the 50 common battery lines, this switchboard provides a mounting for 5 magneto call lines for long-distance operation, including trunk connections.

Ten cord circuits are provided. The conductors of the cords are usually of steel, copper, or tinsel strands. The keys provide for ringing on the calling cord only. This arrangement simplifies the wiring and equipment. The supervisory signal also acts as a retardation coil, through which the battery is fed to the coil circuits. This signal, like the line signal, shows in the form of a target.

The supervisory signal operates when the cord is in use and clears when the parties hang up. A movement of the user's hook up or down operates this signal.

The line signal is thrown when the calling party removes his receiver from the hook and is restored automatically when the operator inserts the answering plug.

The common battery is bridged on the line through the supervisory signals.

The operator's circuit has a standard common battery induction coil, which is connected to battery through a retardation coil, and has a condenser bridged across the source of current supply. A condenser is also placed in the secondary circuit to prevent a flow of direct current when the listening key is thrown.

The breast transmitter or suspended type transmitter and single-head receiver which form the operator's equipment are connected to wing-nut binding posts in cabinet of switchboard by means of suitable cords. The operator's transmitter is provided with a cut-out switch suitably designated.

The night-bell circuit provides a relay and vibrating bell and operates, if desired, whenever a call is received.

The circuits of this switchboard are shown in figure 6–10. Reference to this figure indicates that when the subscriber's hook *H* is up current flows from the battery through the jack contact *C* to the subscriber's instrument, through the transmitter and induction coil back to jack contact *K*, and thence through line signal to battery.

When the answering plug is inserted in the jack *J* the line signal is cut off and falls back. Current now flows to the user's instrument through one winding of the supervisory signal *S*, through contacts of key *R*, through cord to tip of answering plug, through jack, returning to the battery through the other side of the jack, cord, and key and the other winding of the supervisory signal. The operator depresses listening key *K*, and the user's voice currents flow into the receiver circuit at the switchboard. The calling cord of the same pair as the answering cord just used is now inserted in the jack corresponding to the line desired, the key *R* is depressed, the generator turned, and the connection is established. As soon as the plug is inserted current flowing through the supervisory signal shows "busy" until both parties hang up their receivers. Should either party desire to attract central's attention a movement of the switch hook will cause this signal to flutter.

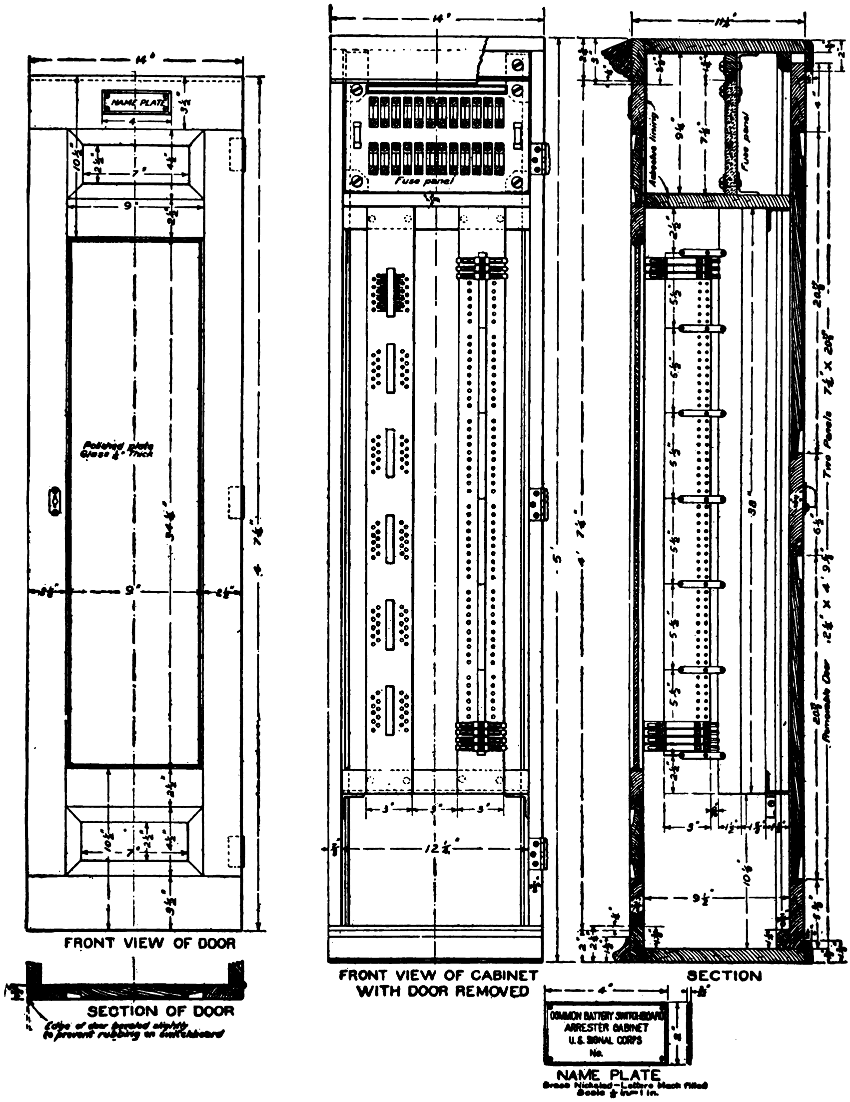

Fig. 6–7.—SWITCHBOARD, TELEPHONE, PROTECTOR CABINET.

Part No.	Name.	Reference No.
1	Cabinet only	
2	Glass for door	
3	Door, front	
4	Door, back	
5	Panel fuse complete	
6	Slate for fuse panel	
7	Screws for mounting	
8	Angles for mounting, large	
9	Angles for mounting, small	
10	Fuse, baby, 3-ampere	
11	Fuse, telephone, ½-ampere	

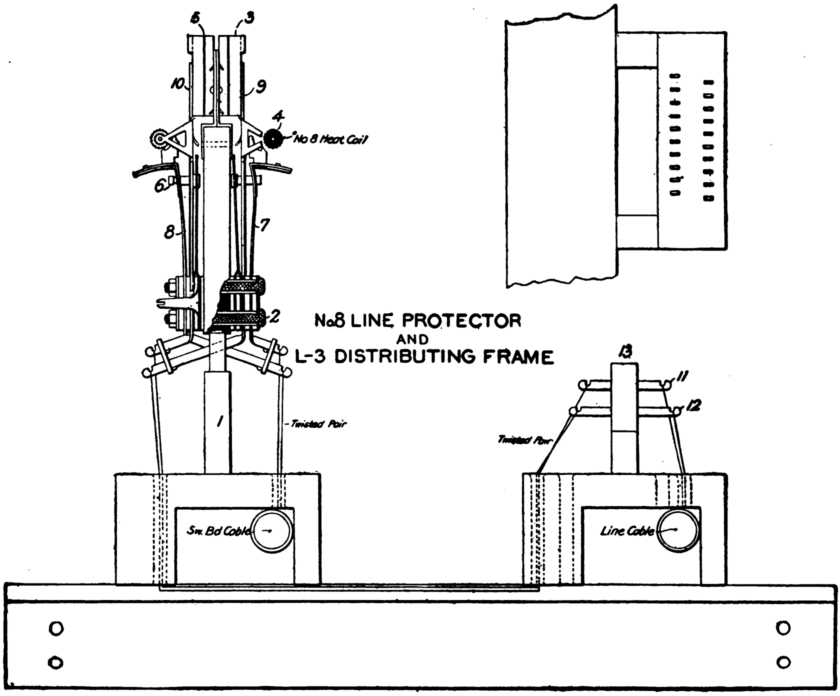

Fig. 6–8.—SWITCHBOARD, TELEPHONE, COOK PROTECTOR, DETAILS.

Part No.	Name.	Reference No.
1	Arrester, complete, without heat coil	....
2	Arrester mounting	1
3	Bolt and nut	2
4	Carbons, pairs	3
5	Coil, heat	4
6	Mica	5
7	Spacer	6
8	Spring, arrester, right-hand	7
9	Spring, arrester, left-hand	8
10	Spring, line, right-hand	9
11	Spring, line, left-hand	10
12	Terminal, cross-connecting, small	11
13	Terminal, cross-connecting, large	12
14	Terminals, cross-connecting, set of 20, with mounting	13

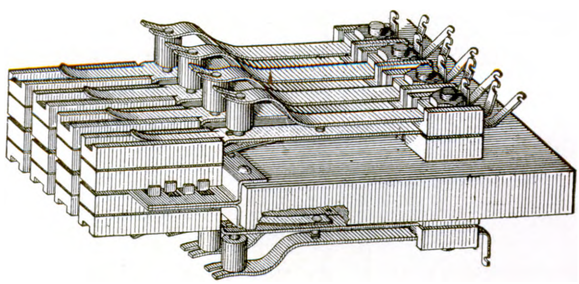

Fig. 6–9.—SWITCHBOARD, TELEPHONE, WESTERN ELECTRIC PROTECTOR, DETAILS.

The night-bell circuit of this central energy switchboard is shown in figure 6–11. It will be seen that when the visual signal operates a current will flow

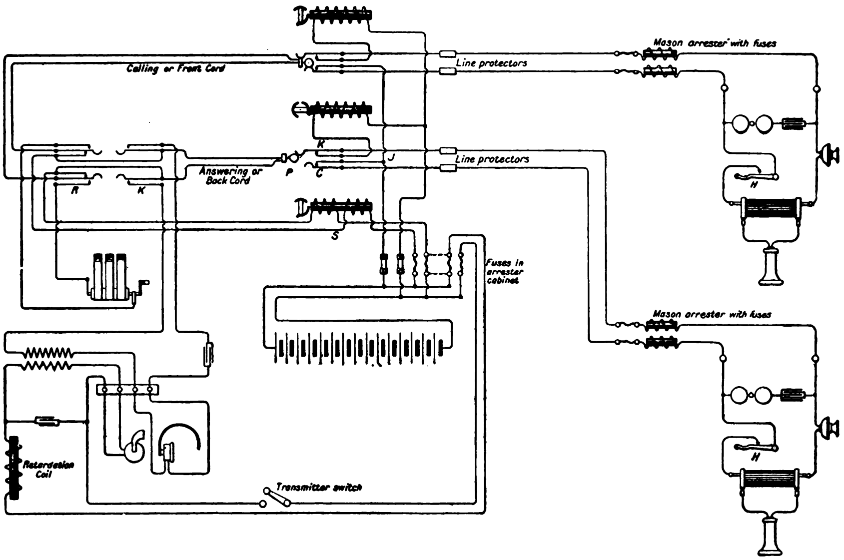

Fig. 6–10.—SWITCHBOARD, TELEPHONE, VISUAL, CIRCUITS.

from the common battery through the contact of the night-bell key *K*, thence through the relay, thence through the contact of the armature of the signal,

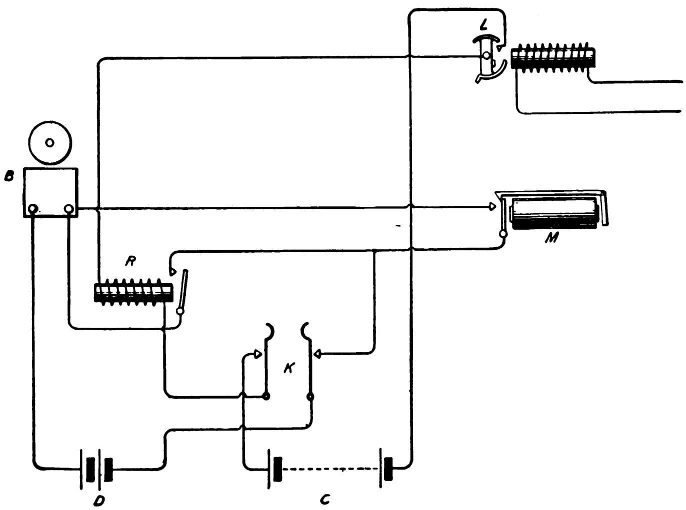

Fig. 6–11.—SWITCHBOARD, TELEPHONE, VISUAL, NIGHT-BELL CIRCUIT.

returning to the battery. The operation of the relay, however, permits current to flow from the dry cells *D* through the right-hand contact of the key *K*, thence through the bell and back to the battery *D*. When the magneto drop operates, current will flow from the battery *D* through the right-hand contact of the key *K*, through the armature contact of the magneto drop *M*, through the bell *B*, returning to the battery *D*.

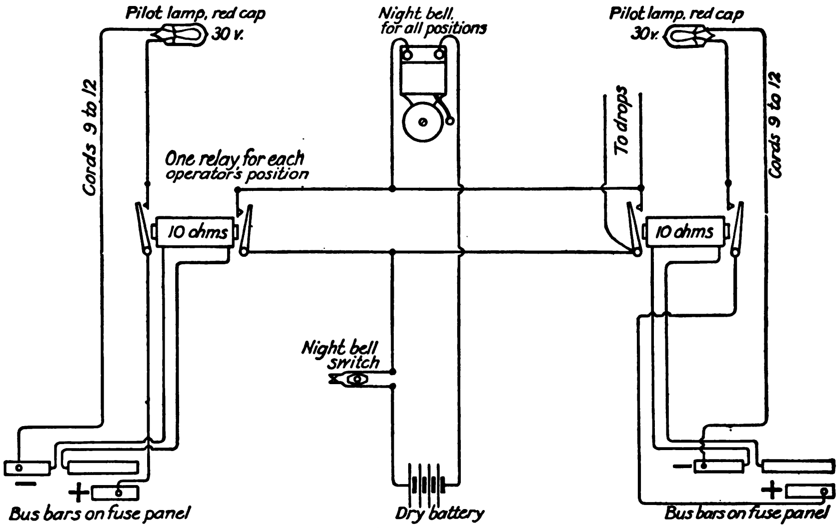

Fig. 6–12.—SWITCHBOARD, TELEPHONE, 200-LINE, NIGHT-BELL CIRCUIT.

It will be noted that with the visual signal a relay is utilized to close the night-bell circuit. The reason for this is that the contacts of the visual signal are of a delicate nature and it is advisable to reduce to a minimum the current strength broken at these contacts.

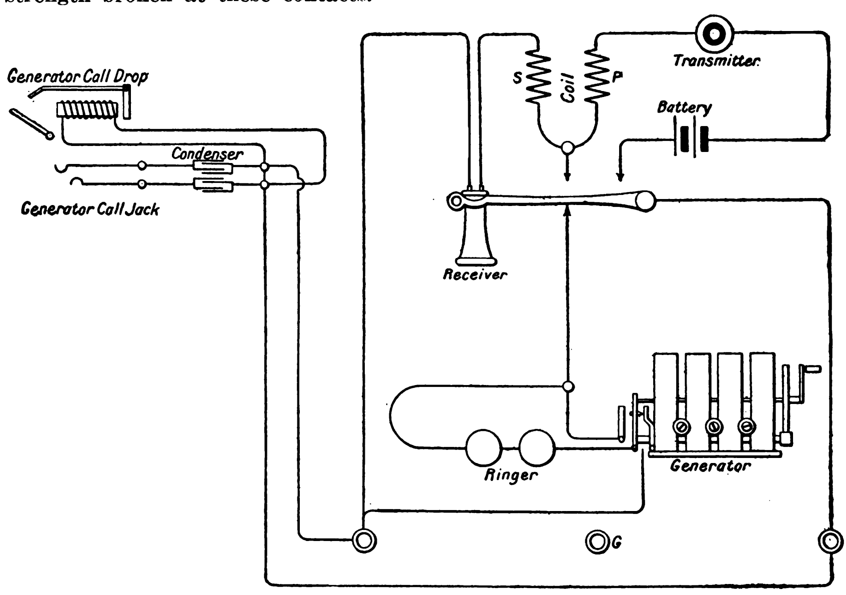

Fig. 6-13.—SWITCHBOARD, TELEPHONE, 200-LINE, GENERATOR DROP CIRCUIT.

With the 200-line size only, the night-bell circuit is as shown in figure 6–12. With this size, a small 30-volt pilot lamp is lighted by means of a relay whenever any one of the line signals is operated.

Where the length or resistance of lines make common battery signaling impracticable, or where the line is contained in submarine cable a considerable distance, one of the generator call drops is brought into service.

Figure 6–13 shows approved method of wiring in a circuit of this kind where a telephone instrument is installed at the distant station.

It will be noted that the telephone connected to such a circuit must be of local battery or composite type, and that the line between switchboard and substation is not connected to battery leads at either end. In other words, the line is "dead," except when calling or talking is in progress, and then the currents imposed upon the line are alternating or pulsating. This condition is highly desirable where line is contained in submarine cable, especially if the insulation of cable be rubber compound.

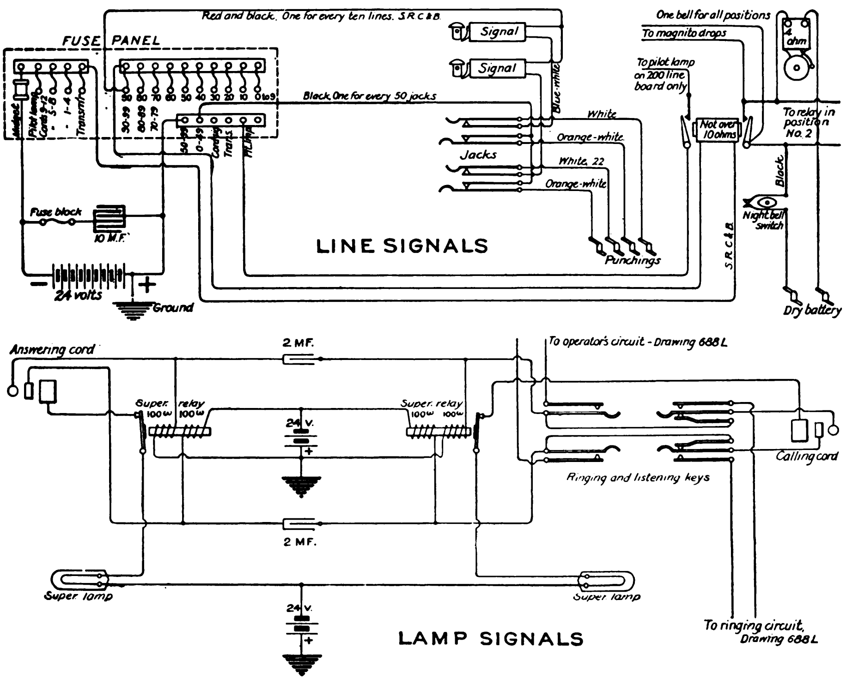

Fig. 6–14.—SWITCHBOARD, TELEPHONE, VISUAL LINE SIGNAL, LAMP SUPERVISORY CORD CIRCUIT.

The condensers in series with each line at the switchboard prevent the common battery coming in direct contact with the line, while the alternating and pulsating currents employed in calling and talking are not prevented from reaching line by the condensers.

What has just been stated of the switchboards equipped with "visual signal for line signal and visual signal for supervisory signal" is true of the switchboard having "visual signal for line signal and lamp signal for supervisory signal," except that instead of having visual signals in the cord circuits a small 30-volt electric lamp with colored caps (usually red), both of which are mounted on key shelf, are supplied.

By means of a relay for each cord, when the operator plugs into a jack, the lamp for that particular cord lights and is extinguished when party called removes receiver from hook. When either of the two parties connected by means of the telephone switchboard hang receiver on hook, the relay associated with the particular cord used for connection is operated. This in turn lights the small lamp associated with that particular cord, and the operator is thereby notified that line is not in use.

This type of switchboard is now furnished for the 50, 100, and 200 line size.

Figure 6–14 shows the cord circuit. The other circuits of the switchboard are identical with those of the switchboard previously described.

LAMP SIGNALS FOR LINE SIGNALS AND LAMP SIGNALS FOR SUPERVISORY SIGNALS.

For all telephone switchboards having a line capacity exceeding 200, lamp signals for both line and supervision are supplied. Where the line capacity of the switchboard is between 100 and 400, it is constructed for operation by two operators (two-position switchboard), although provision is made whereby one operator may use either operator's set for operation of the whole switchboard by merely closing a switch. This arrangement is made in order that one man only need be kept on duty during period that few calls are made.

The only size above 300-line capacity that has been furnished by the Signal Corps is 600-line. This switchboard is a three-position (three operators) multiple switchboard of commercial type. The two outside positions are multipled. This means that either of the two outside operators may plug into jacks connected to each of the lines terminating at the other's position. These jacks are mounted directly above the regular line jacks. The operator at

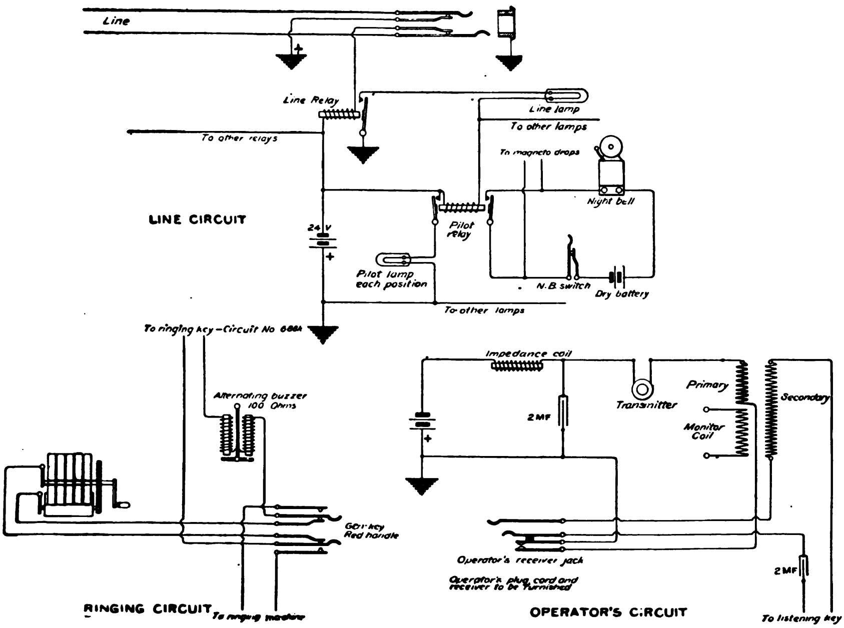

Fig. 6–15.—SWITCHBOARD, TELEPHONE, LAMP LINE AND LAMP SUPERVISORY SIGNALS, CIRCUITS.

central position is able to reach the line jacks of either of the other positions, consequently the multiple jacks are not furnished for this position.

The principal circuits of all telephone switchboards above the 200-line size furnished by the Signal Corps are similar, and are shown in figures 6–15 and 6–16, while by referring to figure 6–17, a view of a 300-line switchboard with distributing frame installed about 3 feet from switchboard may be seen. Figure 6–3 shows this same distributing frame upon which are mounted strips supporting

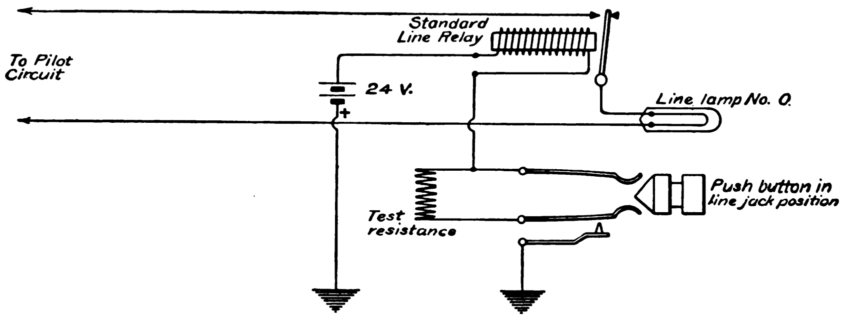

Fig. 6–16.—SWITCHBOARD, TELEPHONE, LAMP LINE AND LAMP SUPERVISORY SIGNALS, TEST CIRCUIT.

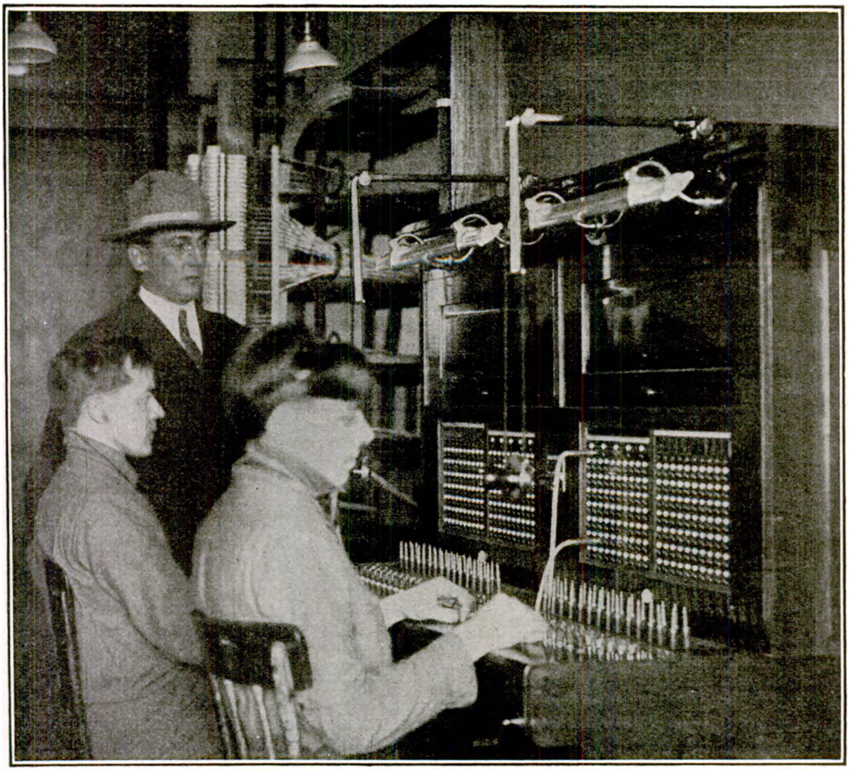

Fig. 6–17.—SWITCHBOARD, TELEPHONE, LAMP LINE AND LAMP SUPERVISORY SIGNALS, IN OPERATION.

metal punchings to which incoming lines are terminated, also the protectors previously described in this chapter. The cross-connecting of the lines to protectors in this installation was accomplished by using pothead wire, and the switchboard cables from protectors to switchboard were encased in an oak runway, supported by 1 by ¼ inch iron pieces.

In addition to the equipment herein described for switchboards, all sizes above the 200-line size are usually equipped with a number of special relays used in the operation of lines connected to the common battery circuits of commercial exchanges. It must be borne in mind that in making such a connection the common battery of the commercial exchange is connected to the line which is connected to the Signal Corps switchboard, also that supervision at both switchboards must be maintained. This is accomplished by means of a locking relay for each such line connected to Government switchboard.

Any of the switchboard cords may be used for connection with jacks associated with these relays. The circuits usually employed with these locking relays are shown in figure 6–18. In tracing these circuits it will be noted

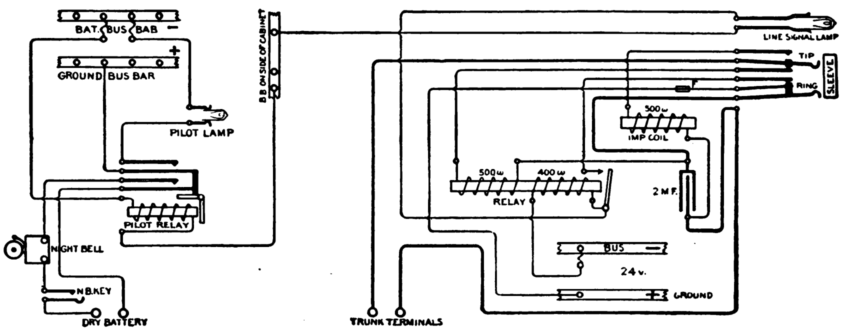

Fig. 6–18.—SWITCHBOARD, TELEPHONE, LOCKING RELAYS, CIRCUITS.

that a condenser prevents the common battery of the commercial exchange completing a circuit through common battery of Government exchange when the cord plug of Government exchange is inserted in trunk jack. Also, that when the operator of the commercial exchange impresses a ringing current upon the line in the usual manner, one winding of the locking relay is in the circuit. This causes armature of locking relay to vibrate, due to ringing current being alternating in character. A slight vibratory movement of the armature closes a contact, which in turn closes a circuit consisting of the other winding of relay in parallel with trunk-line lamp and pilot relay in series and the combination in series circuit with the common battery of Government exchange. The trunk-line lamp remains lighted when commercial operator ceases to ring, due to armature of locking relay being held in contact by the direct current.

When Government operator withdraws cord plug from jack, upper contact of jack is broken, and the supervisory lamp of commercial switchboard is thereby lighted.

For Government operator to call commercial operator, it is only necessary to insert cord plug in one of the trunk jacks. This operation signals the commercial operator in exactly the same manner as removing receiver from hook of a telephone.

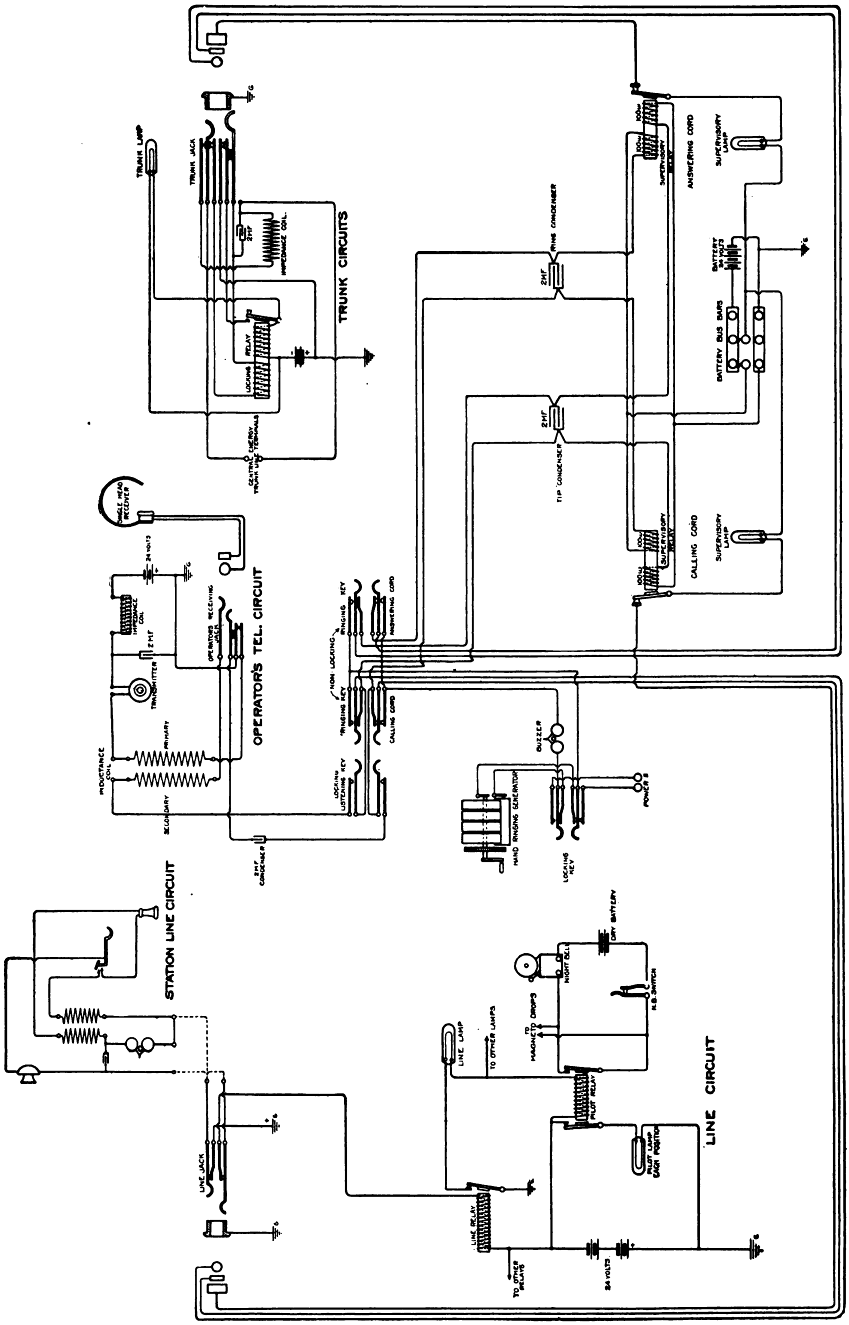

Fig. 6-19.—SWITCHBOARD, TELEPHONE, LAMP LINE AND LAMP SUPERVISORY SIGNALS, PRINCIPAL CIRCUITS.

Supervision at Government switchboard is accomplished by means of supervisory lamp in one side only of cord circuit.

Figure 6–19 shows the principal circuits in one diagram of lamp-line signals and lamp-supervisory signals switchboard.

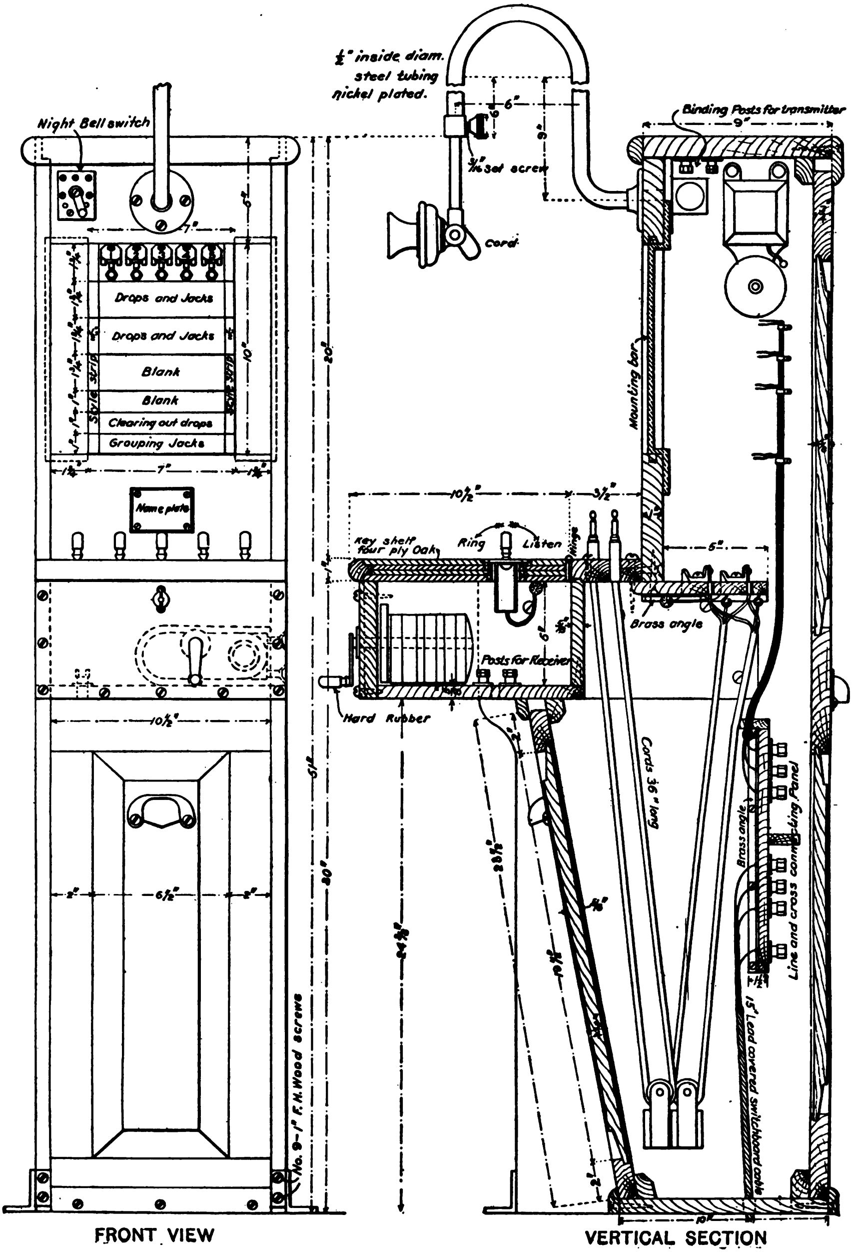

Fig. 6–20.—SWITCHBOARD, TELEPHONE, LOCAL BATTERY TYPE, 15 LINE.

MAGNETO SWITCHBOARDS (LOCAL BATTERY TYPE).

Magneto switchboards, or local battery type, are usually provided for small posts and for temporary installations where conditions at post do not warrant the installation of the standard common battery system.

The operation and maintenance of such systems is comparatively simple. They may consist of a minimum of 12 telephones.

For the small installations, the Signal Corps has applied a 15-drop switchboard. These were made under Signal Corps specifications and are shown in figures 6–20 and 6–21.

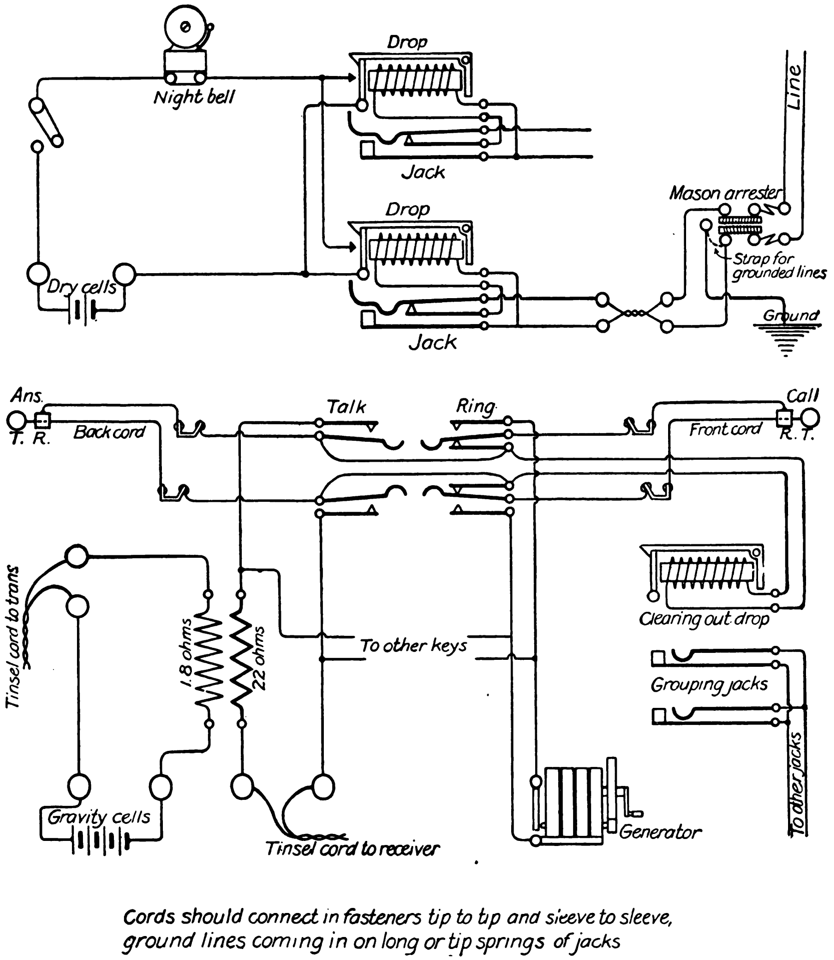

Fig. 6–21.—SWITCHBOARD, TELEPHONE, LOCAL BATTERY TYPE, 15 LINE, CIRCUITS.

This switchboard consists of a neat oak cabinet accommodating 15 combined drops and jacks, 5 pairs of cords with clearing-out drops, and 5 grouping jacks. The operator is provided with a single head receiver, and the switchboard has an adjustable operator's transmitter and the usual night-bell circuit.

An arrester cabinet providing for an ultimate installation of 20 Mason or similar lightning arresters with fuses accompanies this switchboard, sufficient cable being provided to reach from the usual location of the switchboard to the arrester cabinet usually installed on the wall at the rear of the switchboard. The operator's circuit is usually operated by 4 gravity cells.

The circuit is as follows (fig. 6–21):

The calling party signals central by a magneto call, throwing the line drop. The operator inserts an answering plug (opening the drop circuit and at the same time automatically restoring drop shutter) and places key into talking position.

The connection is established by inserting the calling plug into desired line jack. The conversation completed, the usual ring off throws the clearing out drop, signaling the operator to disconnect. All instruments operating through this board are on local battery.

Grouping jacks are provided to connect several lines together by placing answering plug in line jack and calling plug in grouping jack.

The operator's circuit is of the simple induction principle used in ordinary telephones.

These boards are wired for 15-line drops only, and it is not practicable to increase their line capacity without sending them to some Signal Corps supply depot. It is not probable that any more of this type of board will be issued.

This board should have four cells of gravity battery, size 5 by 7, for the operator's telephone, as this telephone has normally a closed circuit, and therefore dry cells or any other type of open-circuit battery should not be used unless a cut-out switch is provided.

50-LINE MAGNETO SWITCHBOARD.

For local-battery telephone systems of more than 15 and not exceeding 50 lines the Signal Corps has in service a number of local-battery magneto switchboards. These boards have an ultimate capacity of 50 lines and are so wired. They are supplied to posts with 20, 30, 40, or 50 drops installed, depending upon the number of telephone lines required. In this board the operator's telephone is nominally a closed circuit, and four cells of gravity battery, 5 by 7 size, should be used.

Additional drops and jacks can be supplied for these boards and installed with facility at any time to increase the capacity up to 50 lines, as the necessary wiring is already complete.

This switchboard is a stock article of commercial use. Figures 6–22 and 6–23 illustrate the appearance and circuits of this equipment.

It has an oak cabinet and is provided with hand generator, 5 pairs of cords with listening and double ringing keys, bridged supervisory magneto drop signals, hand generator and buzzer which can be cut into the ringing circuit as desired for test, two keys for these various ringing circuits, and operator's transmitter and head receiver complete.

Figure 6–23 shows the circuit of this switchboard. It will be seen that the line signal is bridged across the line jack and is cut off from both sides of the line when the plug is inserted.

The cord circuit is the usual circuit with bridged supervisory signal, which is rung down by the stations connected for call when they ring off at end of the conversation.

The red keys on the left-hand side of the keyboard are those shown in the ringing circuit. By throwing the key it is possible to cut the buzzer in series with the ringing circuit. This is desirable when a line indicates a defective condition. The condition of the line in regard to open or short-circuited wires will be indicated by the action of the buzzer, its loudness being determined by the resistance in the line for a uniform rate of turning of the hand generator. On some of the boards the key provided for switching the ringing circuit from power to hand generator, and vice versa, is so wired that it is

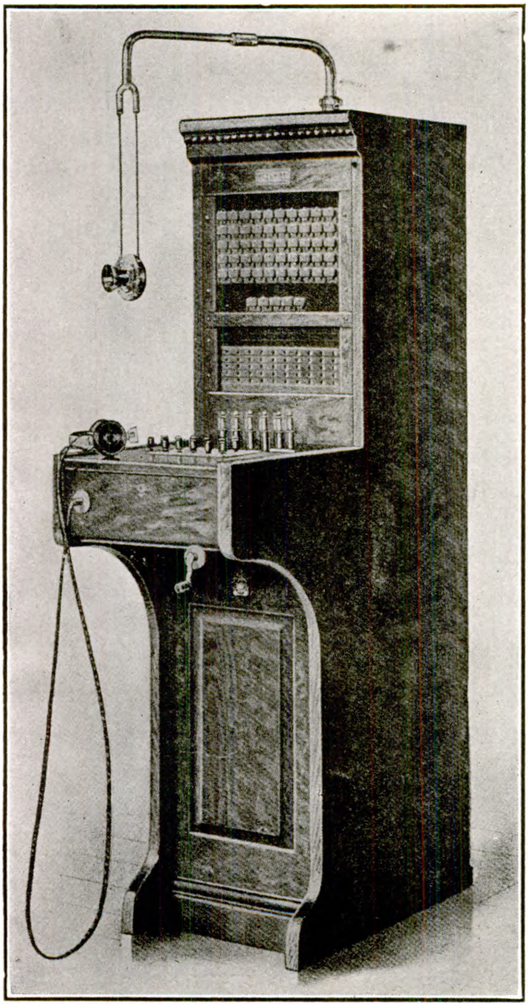

Fig. 6–22.—SWITCHBOARD, TELEPHONE, LOCAL BATTERY TYPE, 50 LINE.

necessary when using the hand generator to throw the key over from the normal position. Inasmuch as power-ringing current for these boards is seldom available and is not provided, this key should be rewired so that the hand generator is connected directly into the ringing circuit while the key is in its normal position.

If power current should be available, it should be connected to the springs marked "generator, Nos. 1 and 2," on the terminal board of the switchboard and the key circuit retained in its present form.

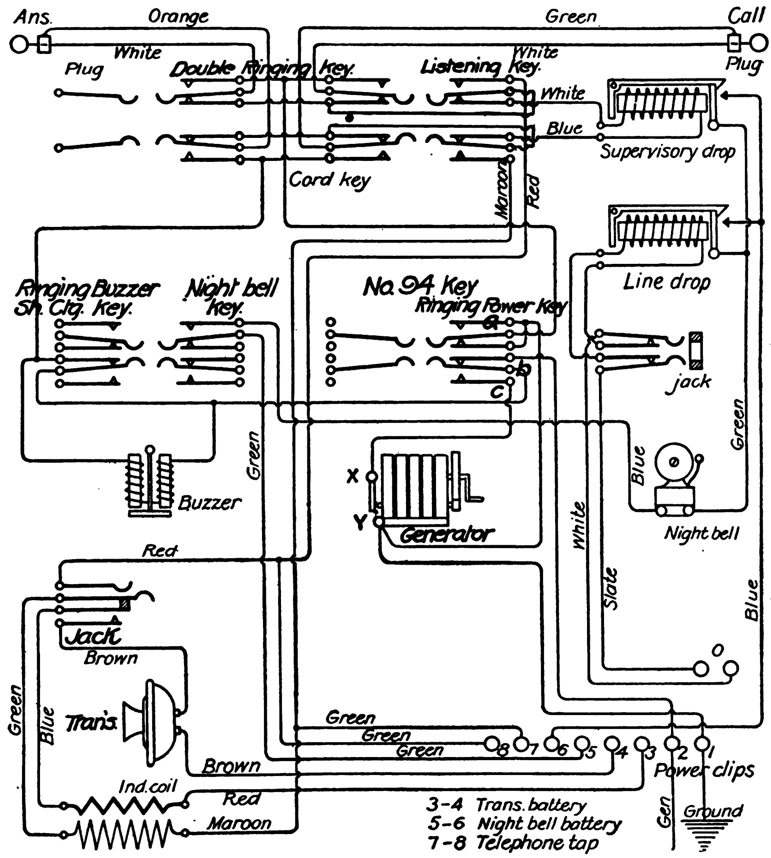

Fig. 6-23.—SWITCHBOARD, TELEPHONE, LOCAL BATTERY TYPE, 50-LINE, CIRCUITS.

It has also been found in some cases that the generator armatures of these switchboards continue to revolve after a call has been made, thus unscrewing the generator handle from the driving shaft. To avoid this a high resistance will be provided to be bridged across terminals X and Y of the hand generator shown in figure 6–23, in order to furnish a slight load for the generator and cause the armature to stop as soon as the generator handle is released. A requisition should be made for these resistances wherever their use is considered to be of advantage.

CORDLESS SWITCHBOARD.

Figures 6–24 and 6–25 show a special cordless magneto type switchboard designed to meet special conditions that obtained in connection with the installation of a post telephone system at the Army Remount Depot near Front Royal, Va.

As it was impracticable to furnish a switchboard operator in this instance, the switchboard is operated by a clerk during office hours and a watchman at other times. The switchboard is supported by a table placed beside the clerk's desk.

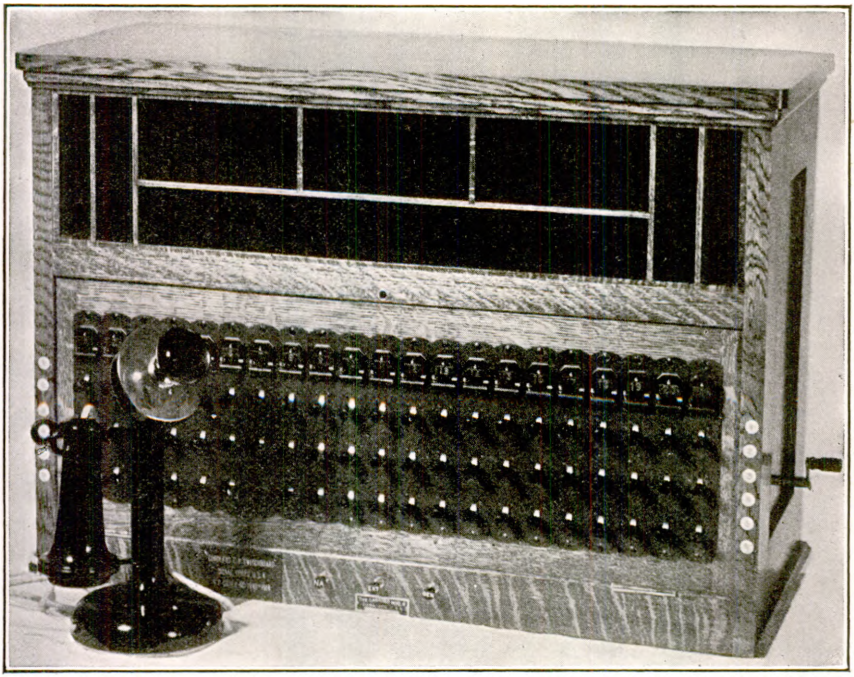

Fig. 6–24.—SWITCHBOARD, TELEPHONE, LOCAL BATTERY, CORDLESS.

It is only necessary to operate keys to obtain desired cross connections. The switchboard is of 20-line capacity and, as shown in the figures, the operator's set consists of an ordinary telephone desk stand with hand receiver. Figure 6–26 is a circuit diagram of the switchboard.

By depressing a locking key (marked "*NA*" in figure 6–24) a small buzzer contained in the cabinet is so connected in circuit that the buzzer will operate when a call is received. By depressing an additional locking key (marked "*EXT*" in fig. 6–24) the buzzer is cut out of circuit and a loud ringing water-tight bell, located outside of the administration building, is made to operate when a call is received. The latter is used to notify the watchman, who is required to make regular rounds of the post at night.

The operator's circuit and bell and buzzer alarm are operated by means of No. 6 reserve dry cells contained in the cabinet of the switchboard.

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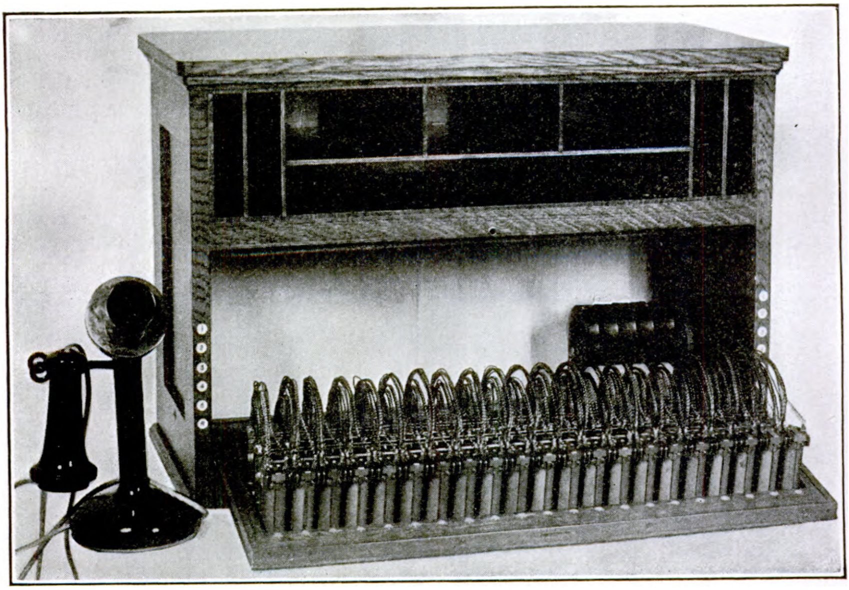


Fig. 6-25.—SWITCHBOARD, TELEPHONE, LOCAL BATTERY, CORDLESS, OPEN.

INSTALLATION OF TELEPHONE SWITCHBOARDS.

Care should be taken in unpacking switchboard apparatus so that it will not be injured. Different manufacturers use various methods of packing material so it will not be injured in transit. Braces will be found in the packing which must be removed as the material is taken out. If the apparatus is found to be in an injured condition, note should immediately be made of this fact, witnesses called in for verification, and a report immediately submitted so that proper action may be taken.

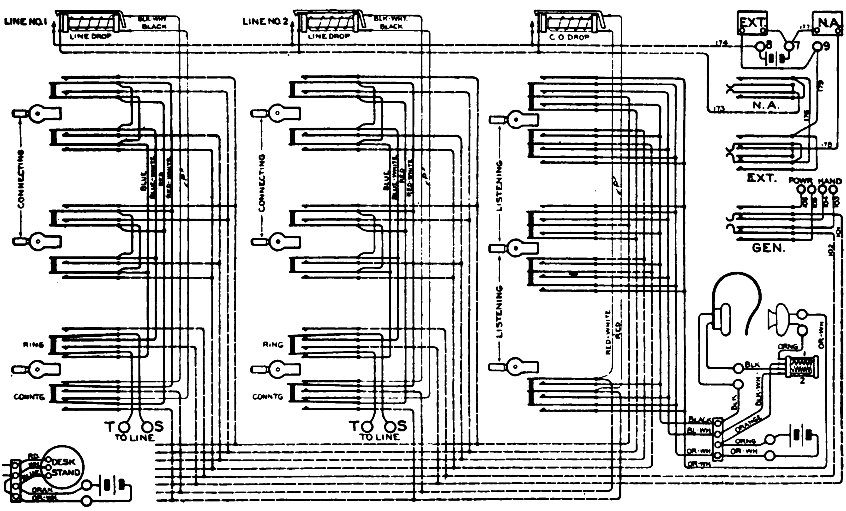


Fig. 6-26.—SWITCHBOARD, TELEPHONE, LOCAL BATTERY, CORDLESS, CIRCUITS.

The cord weights are usually tied up and fastened. Relays which have metal covers are usually filled with paper so that the relay will not be injured by shaking. The apparatus should be given a thorough cleaning and cleared with a bellows. Care should be taken that not any of the extra parts are thrown away with the excelsior or other packing materials. All fuses should be tested and care taken with the remainder of the apparatus.

Blue prints and instructions usually accompany each switchboard, and these should be followed in the erection of the material.

Telephone switchboards for post systems are usually installed in the administration building, as stated in General Orders, No. 5, War Department, 1913. In selecting the location consideration should be given the following requirements in order to insure good telephone service: The room selected should be quiet and free from intruders, so that the operator's attention may not be diverted from his duties. Sleeping quarters for the operators are also desirable if all-night service is contemplated. The necessity of running the lead-covered cables from the switchboard room to the outside circuits should also be remembered, as the protector equipment must always be located in the same room with the switchboard.

The switchboard should be located so that the light falls on the front of the board and so that the operator is not compelled to face a strong light. The back of the boards that are not built for installation on the wall and hinged to swing out for inspection should never be nearer than 2 feet to the wall so that the wiring is always accessible for inspection.

Switchboard cable is invariably used for connecting appropriate line terminals in switchboards with associated protectors in protector cabinet or on distributing frames.

The standard Signal Corps switchboard cable consists of 20 twisted pairs of conductors, with one spare pair and one odd wire. The conductors are of soft copper wire, 25.3 mils diameter, insulated by two wrappings of silk applied spirally in reverse directions, and a wrapping of cotton. The twisted pairs are assembled, impregnated with beeswax and wrapped with cotton, then a wrapping of paper, a layer of tin or lead foil wrapped spirally and lapped, another wrapping of heavy paper, a wrapping of cotton, and a heavy, close braid of cotton treated with fireproof slate-colored paint. The cotton wrapping of one conductor of each pair is white, and the other a color conforming to table which follows. In connecting this cable, the following arrangement of colors should always be adhered to. Under no conditions should any other sequence of colors be followed, as this arrangement is standard, and is a very important guide to the repair man who maintains the system.

SWITCHBOARD CABLE, COLOR SCHEME.

First pair	Blue.	White.
Second pair	Orange.	White.
Third pair	Green.	White.
Fourth pair	Brown.	White.
Fifth pair	Slate.	White.
Sixth pair	Blue-white.	White.
Seventh pair	Blue-orange.	White.
Eighth pair	Blue-green.	White.
Ninth pair	Blue-brown.	White.
Tenth pair	Blue-slate.	White.
Eleventh pair	Orange-white.	White.
Twelfth pair	Orange-green.	White.

Thirteenth pair	Orange-brown.	White.
Fourteenth pair	Orange-slate.	White.
Fifteenth pair	Green-white.	White.
Sixteenth pair	Green-brown.	White.
Seventeenth pair	Green-slate.	White.
Eighteenth pair	Brown-white.	White.
Nineteenth pair	Brown-slate.	White.
Twentieth pair	Slate-white.	White.

Ordinarily switchboards are not provided with the switchboard cables connected, and requisitions should specify the length of cable required to reach the protector cabinet. The line cable should be neatly formed as directed in a later paragraph and carefully soldered to the line terminals, care being taken to make well-tinned joints, as often the resin deposited when soldering is mistaken for solder, and also that corresponding wires of the line cable pairs are connected to similar sides of the switchboard lines. In connecting the line cables to the protector cabinet the method adopted must be such that there will be no likelihood of the cable becoming wet when the floor is scrubbed or in any other way. For this reason, if the cable is run under the floor, provision should be made for this contingency, as the line cables usually provided and adopted for this work have no particular moisture-resisting properties.

The outside line cables should be potheaded above the floor, the wiped joint resting on the floor and taking up any strain that might otherwise be upon the connections in the terminal or protector cabinet. For magneto switchboards which have separate protector cabinets installed on the wall and apart from the switchboard proper, the top of the pothead sleeve should terminate just inside the bottom of the cabinet and pothead should be clamped securely to blocks on wall and protected from injury.

Inside the cabinet the wires should be formed and laced and permanently held in place by small leather straps so that the work is permanent in every way.

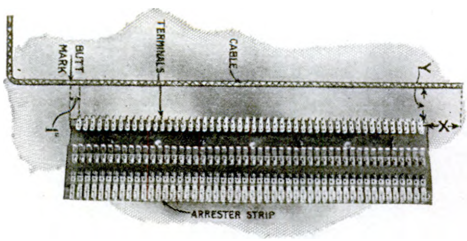


Fig. 6-27.—SWITCHBOARD, TELEPHONE, FORMING CABLE CONDUCTORS.

All telephone switchboards should be installed in a permanent manner and the scheme of wiring followed which will minimize trouble in maintenance work.

The telephone switchboard should always be bolted to the floor so that it will be held permanently in its position and also because the boards are usually top-heavy and not intended to stand unsupported.

The necessary cord, magneto, line, and bus-bar condensers are installed at the rear of the central energy switchboards. A diagram showing the arrangement of this apparatus is provided with the different boards. Forms should be made for these connections, allowing as much slack as possible for emergencies.

In wiring through the floors porcelain tubes of ample size should be made use of, and great care should be taken in all the cabling that no damage may result to the installation from carelessness on the part of the occupants of the building in which the board is installed.

Where cable forms are required, and particularly at the ends of the cable which is to be used to connect the line wires to the arrester strips, cable forms should be made up as follows:

After the cable is laid in its permanent position its free ends shall be laid parallel to terminals to which it is to be attached. The end of the cable should extend a distance *X* (fig. 6–27) beyond the top clip of the strip. At the bottom of the strip a butt mark should be made about an inch below the lowermost clip, to which this cable is to be attached.

The outer covering of the cables should then be removed from the butt mark, so as to expose the twisted pairs. This is accomplished by the use of a sharp

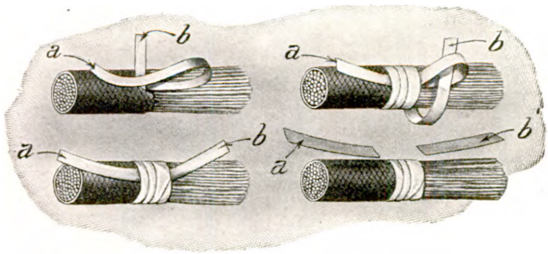


Fig. 6–28.—SWITCHBOARD, TELEPHONE, FORMING CABLE CONDUCTORS.

knife, being careful not to cut the insulation of the wires. The knife should be held in a slanting direction to the cross section of the cable in this operation. In cutting the cable around the butt mark, so as to leave a clean end, care should be taken not to cut the insulation or damage the wires. All binding strips should be removed with the sheath from the cable.

A strip of cotton tape one-half of an inch in width should now be bound tightly around the exposed edges of the cable covering. The operation of bind-

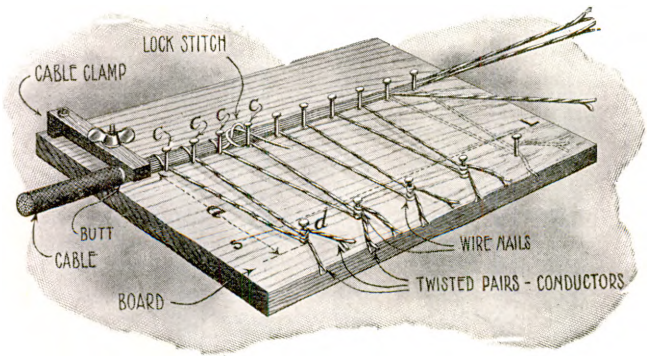


Fig. 6–29.—SWITCHBOARD, TELEPHONE, FORMING CABLE CONDUCTORS.

ing the cable at this point is known as "butting" and should proceed as shown in figure 6–28. The tape is first looped, and then its long end is wound around the cable four or five times and threaded through the loop which was first formed. The end *B* is then drawn under the turns by pulling the end *A* and closing the loop. Next, the loose ends are cut away and a coating of shellac is applied, completing the butt. The exposed twisted pairs of the standard switchboard cable should now be put in boiling yellow beeswax up to the butt until all the bubbles disappear from the liquid. The purpose of this wax is to expel all moisture and improve the insulation of the wires, and also to prevent the braid loosening up while the form is being completed. All surplus wax should be gently beaten from the cable with a stick when it is removed from the boiling pan.

The cable is now clamped at the butt to the board, as shown in figure 6–29, and each pair of wires is selected in numerical order, according to the color code, dyed in the insulation of the conductor, and drawn into place and fastened around each successive nail. The length of wire allowed between the stem of the cable and the nails is always in excess of that necessary to reach the clips that must be connected. A spare pair of wires is left projecting at the end of the cable, so that it may be used in case any one of the

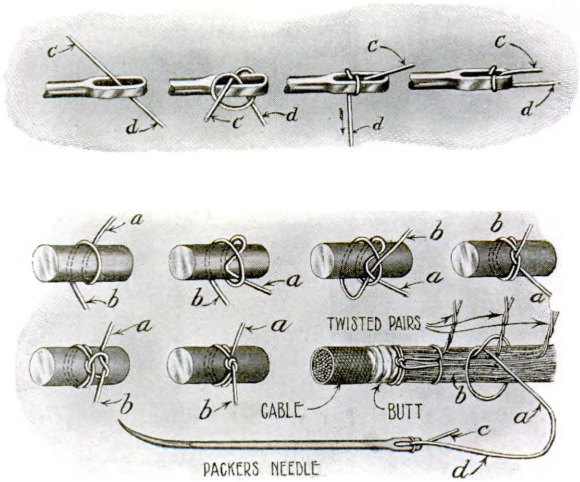


Fig. 6–30.—SWITCHBOARD, TELEPHONE, FORMING CABLE CONDUCTORS.

regular pairs becomes defective. The formed part of the cable is sewed up with a stout waxed linen twine by the aid of a 4-inch packer's needle, which facilitates the passing of the twine under the bunches of wire.

This needle, with the method of threading it, is shown in figure 6–30. Before sewing up, three turns of twine should be taken next to the butt, drawn up taut, and tied with the knot shown, in which *a* is the needle end of the twine and *b* the short end. All line wires are bound together from this point to the end of the twine with what is called a lock stitch, shown in figure 6–30.

A stitch is taken at each nail, and if the space between is over 1 inch an extra stitch should be taken. In making the stitch the needle is passed under the wires and through a loop, as shown in figure 6–31, being careful not to include in the loop the stitched part. The loop should hold without fastening after being completed. The last stitch is reinforced by a knot, *g*, after which it is preferable to take another stitch and knot *h* around the spare wires and the other side of the last regular pair.

Before taking the cable from the forming board the ends of the wires should be cut off even and the insulation removed from the ends of each, using the line *S L*, figure 6–29, as a guide.

The skinning should be done with a sharp knife, drawing it from the line *S L* toward the end of the wire, at the same time pulling off the covering, which will slip off as soon as the threads are severed. Great care must be taken not to nick the wire, as it would then be liable to break at this point upon being moved or handled.

The tips should now be shellacked lightly and allowed to dry. This prevents unraveling of insulation when soldering.

If the wires are to be soldered to the terminal clips, their bare ends should be threaded, through the holes in the clips, up to the insulation and bent back. If no holes are provided, they should be wound close around the notched portion of the clip. Care must be taken to get the insulation out of the notch in the clip or the hole. Only resin solder should be used in making soldered joints. After soldering, the free end of the wire should be cut off close to the clip and each joint tested.

The cable should now be strapped in place with leather saddles. When the forms are installed they may be finished with a coat of white shellac, which keeps the dust and dirt from sticking to the wires due to their having been boiled in beeswax.

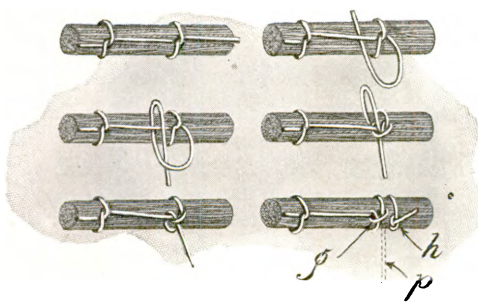


Fig. 6–31.—SWITCHBOARD, TELEPHONE, FORMING CABLE CONDUCTORS.

For the central energy board of from 50 to 100 line capacity, the switchboard cables are sometimes furnished as part of the switchboard, which is usually received with these cables connected to the terminal strips on the back and of sufficient length to reach into the protector cabinet which is erected next to and as part of the switchboard. The code scheme given is followed in all switchboard wiring, but it is sometimes impossible to make up the cable for the protector strip on a temporary form. However, this is easily met as follows:

All cables are butted, as previously described, at the bottom of the arrester strip, after cables are measured off for their permanent position. The wires are then boiled in beeswax, as instructed, and each pair brought through the forming holes of the protector strip in the same order as their connection to line signals. That is, the No. 1 signal is connected to the No. 1 arrester, then when all wires are in place the cables are laced into one stem and the whole shellacked and soldered as in the first case. By this method the arrester strip itself is used as the form for lacing. No excess slack is allowed in this form, care being taken to connect all wires correctly the first time. All extra wires are run to the top of the form and dead-ended. For 200-line and larger, central energy switchboards which have iron frames for supporting their protectors and outside line cables terminal equipment, and which are erected separate from board and some distance from it, according to local conditions, switchboard cables are not provided. These must be made up locally to meet the conditions.

The switchboard will be supplied with one or more spare jacks and drops. One of these jacks should be used for the purpose of testing cords. The magneto line signal should be disconnected from the spare jack and a cell of dry battery should be connected to its associated line terminals. When a plug is inserted in this jack, and the cord is shaken, a "cut-out" will be detected by a rasping noise in the operator's receiver.

The generator call drops should be adjusted so as to fall readily on about five cells of dry battery.

When the switchboard is completely installed, and before it is cut over to the working lines, care should be taken to test for cross talk and incorrect connections in the circuit from the heat-coil terminals to the line jacks. Under no conditions should the switchboard be put into commission when any cross talk is noticeable. It will be found sometimes that the key contact fails to break on the operator's listening circuit, and thus crosses the lines with the other keys. Dampness in the switchboard may also cause trouble of this kind.

All power connections should be poled alike.

INSTALLATION OF PROTECTIVE APPARATUS.

It is the practice to provide protection at the switchboard room for all lines entering the telephone switchboard even though not any of the line circuits are exposed aerial lines. For local battery systems Mason arresters, or similar individual pair arresters consisting of a fuse and a multi-discharge lightning arrester, are sufficient. For central-energy systems heat coils and lightning arresters are provided.

MAGNETO SWITCHBOARD PROTECTORS.

The protection for small magneto switchboards is usually installed separately from them; in most cases on the wall near by and within sight of the operator. A cabinet of the same wood and finish as the switchboard is provided for the installation of the necessary number of Mason arresters.

The connections between the switchboard and the protector cabinet should be made by means of switchboard cable described elsewhere in this chapter. The color scheme should be carefully followed.

The forms for both the switchboard and protector ends should be carefully laced, each wire being brought out at its particular line spring or arrester. The switchboard end should be carefully soldered after the wire is passed through the hole and wrapped around the spring. The forms should be treated in a similar manner to that described for common-battery switchboards.

If the switchboard cable is installed under floor, it should be run through bottom of switchboard, coming up directly under the point of arrester cabinet it is desired to enter, protecting it with loricated conduit between the floor and cabinet, and under the floor provision should be made to protect the cable from moisture.

The outside lines should always be brought into the office and cabinet in cable, even though the length of cable is short. If over 12 pair in size this cable will necessarily be paper insulation with lead sheath, and should be pot-headed at both ends to terminate the conductors in rubber insulation. The method of pot heading is described in chapter 4. The pot-head sleeve should extend into the protector cabinet and be protected by loricated conduit or frame construction between the floor and cabinet. Inside the cabinet the pot-head wires should be carefully laced after the wires are brought out to their respective arresters.

These forms should be thoroughly shellacked after they are formed, laced, and tied in place. Never pour hot paraffin over forms of pot-head wire as the rubber insulation would be injured by such action.

CENTRAL ENERGY SWITCHBOARD PROTECTORS.

One pair of lightning arresters and heat coils, as shown in figures 6–8 and 6–9, are provided for each line, both central energy and magneto. In addition a strip for terminating the outside cable pairs is provided which usually exceeds the arrester pairs by 30 per cent, as necessarily more outside cable pairs are installed than will be actually used by lines.

These arrester and line strips for the 50 and 100 line switchboards are installed in a cabinet such as is shown in figure 6–32.

The cabinet shown is erected against the telephone switchboard and bolted thereto so that in effect they comprise one cabinet or fixture. The local conditions may affect their relative positions, but the door of the protector cabinet can be hinged on either side and the strips changed inside so any condition can be met.

The two cabinets are exactly alike in finish and essential dimensions and built to be erected together.

The switchboard cables from the 50 and 100 line switchboards are usually connected to that end when received, and sufficient length allowed for connecting to the arrester strip in the protector cabinet, to which they are run by cutting a hole in the bottom of the partitions between the two cabinets, and lacing the cables together.

The switchboard cables are " butted " and formed as described in this chapter, the color code being followed carefully, and corresponding numbers on the arrester strip assigned to line signals of same number. The magneto drops are connected immediately below the central energy lines, allowing for full capacity of the switchboard. The full protector equipment is furnished in the protector cabinet for each central energy switchboard.

The 20-pair cables are boiled in beeswax preferably, or paraffin if necessary, and laced up into one form and strapped securely to the back of strip on which arresters are mounted, as shown in figure 6–32. The wires should be carefully soldered to the springs, first wrapping the wire around notch, which is already tinned.

Switchboard cable sometimes supplied by manufacturers with switchboards is insulated with two silk and one cotton covering and has no particular moisture-resisting qualities. It should never be installed under a floor where it may become wet from scrubbing or by any other means. It will retain its insulation when installed in a dry room, but it is not intended for exposure. Neither should this type of cable be used for potheading the outside line cables.

The cables to the outside circuits should be brought to the cabinet in the most workmanlike manner that will meet the local conditions. It is usually possible to bring them into the switchboard room directly under the cabinet by running in walls and under floors. Whenever the cables are exposed in the headquarters building they should be protected by loricated conduits or frame runway. In terminal cabinets they should be potheaded directly under the line terminal strip and arranged to be strapped to the horizontal angle-iron piece holding the arrester and line terminal strips. It may be necessary to move this iron toward the front of the cabinet or provide a new iron strap, as the space usually left between the iron strip furnished and the removable rear door is insufficient for the cable. The potheads and wiped splices should rest directly on the floor of the cabinet and thus take up any strain that may be on the cable.

Signal Corps pothead wire should always be used for these potheads, and where several cables are brought in they are laced into one form on the back of the line-terminal strip to which they are connected.

Rubber-insulated wires should never be boiled in beeswax or paraffin, but the forms should be shellacked after they are laced and soldered in.

The potheads should be carefully aligned when installed and an effort made to use sleeves of the same length and diameter, so that the tops will be level when they are completed.

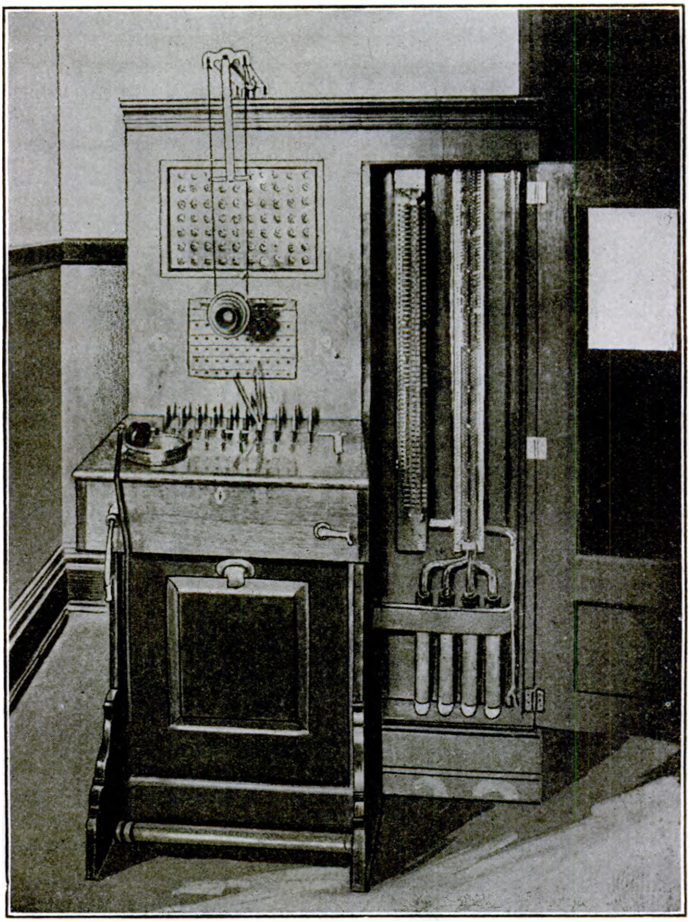


Fig. 6–32.—SWITCHBOARD, TELEPHONE, 50–100 LINE AND PROTECTOR CABINET.

It will be found desirable to install the arrester cabinet on the right-hand side of switchboard, facing it, as this will bring the cross-connecting springs for interconnecting the switchboard cables terminating on the lightning arresters, and therefore the outside line cables, next to each other, simplifying the cross-connection work.

This will require that the door be hinged on the right side. An illustration of this type is shown in figure 6–32.

Outside line cables are brought to the main iron frames provided for 200-line boards in the same manner used for smaller switchboards.

At the main frame the cables are brought through the floor in a position depending on the 20-pair line blocks to which they are assigned.

The potheads rest on the floor and are brought up beside the vertical line of iron braces holding the line blocks to which the cables are connected. The cables to be connected to the top line terminals will naturally be brought in farthest from the bottom block. The potheads should preferably be of same size and height of sleeve and the wires carefully laced and shellacked when formed and in place. The form should be carried straight up and branched to the blocks at the iron braces, to which they should be neatly fastened by tape.

The line blocks number from the top down, and spare blocks should ordinarily be left at the bottom. A cable should be distributed on one vertical row of line terminal blocks.

POWER EQUIPMENT FOR COMMON BATTERY POST TELEPHONE SYSTEMS.

The necessary current for the operation of a common battery or central energy telephone system is obtained from one or more storage batteries. These batteries and all necessary apparatus used in charging them should be given consideration when the installation of a common battery telephone system is contemplated.

The power equipment is one of the most important features of the common battery telephone system, and particular care must be exercised in its installation to insure reliability of service, as failure of the battery renders the entire system inoperative.

At Coast Artillery posts current for the operation of post telephone system is usually obtained from storage battery installed in the fire-control switchboard room in connection with the fire-control system. These batteries are usually of either 80 or 120 ampere hour capacity, depending upon the size of the fire-control system.

The administration building, where the post telephone switchboard is located, may be a considerable distance from the fire-control switchboard room, and the number of pairs in a cable necessary for a suitable battery feed under such conditions would be determined by consulting the following table:

Number of circuits in use simultaneously	1	2	3	4	5	6	7	8	9	10
	Number of pairs required, No. 19 B. & S.									
Distance from battery:										
500 feet	1	1	1	1	1	1	1	1	1	1
1,000 feet	1	1	1	1	1	1	1	1	1	2
1,500 feet	1	1	1	1	1	2	2	2	2	2
2,000 feet	1	1	1	2	2	2	2	2	2	3
2,500 feet	1	1	2	2	2	2	2	3	3	3
3,000 feet	1	1	2	2	2	3	3	3	3	4
3,500 feet	1	1	2	2	2	3	3	3	4	4
4,000 feet	1	1	2	2	3	3	4	4	4	5
1,500 feet	1	1	2	2	3	4	4	4	5	5
5,000 feet	1	2	2	3	3	4	4	5	5	6
5,500 feet	1	2	2	3	4	4	5	5	6	6
6,000 feet	1	2	2	3	4	5	5	6	6	7
6,500 feet	1	2	3	3	4	5	6	6	7	7
7,000 feet	1	2	3	3	4	5	6	6	7	8
7,500 feet	1	2	3	4	5	6	6	7	7	9
8,000 feet	1	2	3	4	5	6	7	7	8	9
8,500 feet	1	2	3	4	5	6	7	8	9	10
9,000 feet	1	2	4	4	6	7	7	8	9	10
9,500 feet	2	3	4	5	6	7	8	9	10	11
10,000 feet	2	3	4	5	6	7	8	9	10	11

With this arrangement it is well to bridge the battery feed at switchboard end with a condenser of approximately 8 microfarads. This condenser tends to short circuit the talking currents and maintain an approximately constant E. M. F. at the switchboard bus bars. Condensers in each cord circuit bridged across the supervisory signals also reduce the tendency to cross talk.

At posts where existing storage battery is not available one or more must be supplied. It should be located as near as practicable to the switchboard and, although not desirable, may be installed in the same room. When the latter location is decided upon a suitable cabinet should be constructed for the battery. This cabinet should be painted inside (two coats) with acid-proof paint and equipped with one or more vents leading to the outside of the building. Figure 6–33 shows such an installation.

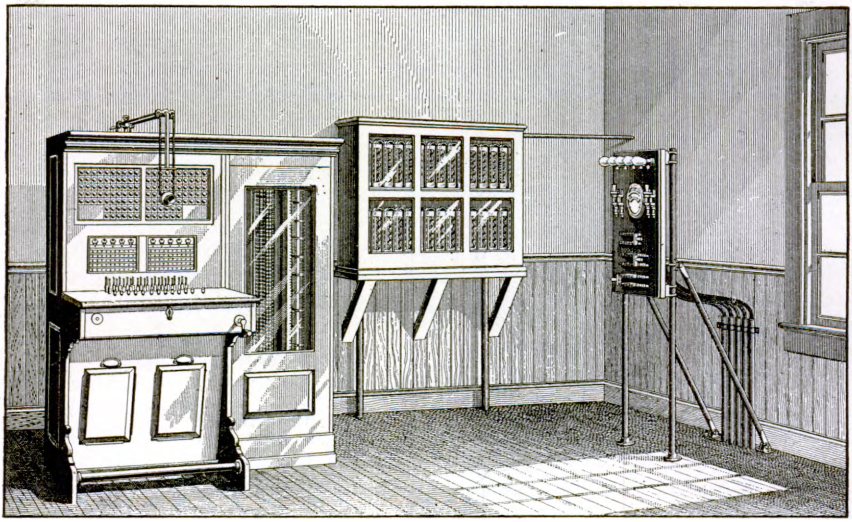


Fig. 6–33.—C. B. TELEPHONE SYSTEM, POWER EQUIPMENT IN SWITCHBOARD ROOM.

The ideal arrangement for the larger systems is to have a separate room, well lighted and ventilated, for the storage battery alone. It can then be mounted on appropriate stands where they can be conveniently examined. Next to this room should be the power switchboard room, where is located the power switchboard used in controlling the power circuits, the motor generator used for charging the storage battery, and the dynamotor or other apparatus for furnishing the ringing current. An additional room, well lighted and ventilated, will be required, in which is located the telephone switchboard and distributing frame with all protector apparatus. The latter room should be of such size that an army bunk may be placed therein in addition to the telephone apparatus, in order that a night operator may sleep in proximity to the switchboard.

In some instances the storage-battery room and power-switchboard room have been formed by the construction of a partition in a room in the basement of the administration building, thereby making two suitable rooms of one room. The telephone switchboard and distributing frame should not be located in a room the floor of which is below the ground level. Where the battery required does not exceed 24-ampere hour capacity the two-plate or coupled type may be used, thereby minimizing the amount of space necessary.

In the past it has been customary to furnish two storage batteries in order that one may be intermittently disconnected from the telephone switchboard while being charged or examined. Experience has shown this practice to be uneconomical and in future, where the battery is charged by a generator, the standard equipment will be one battery (ordinarily 12 cells). If the telephone lines are noisy during the charging of storage battery, a suitable choke coil, connected in series with one of the leads between the generator and storage battery, will usually eliminate such a defect.

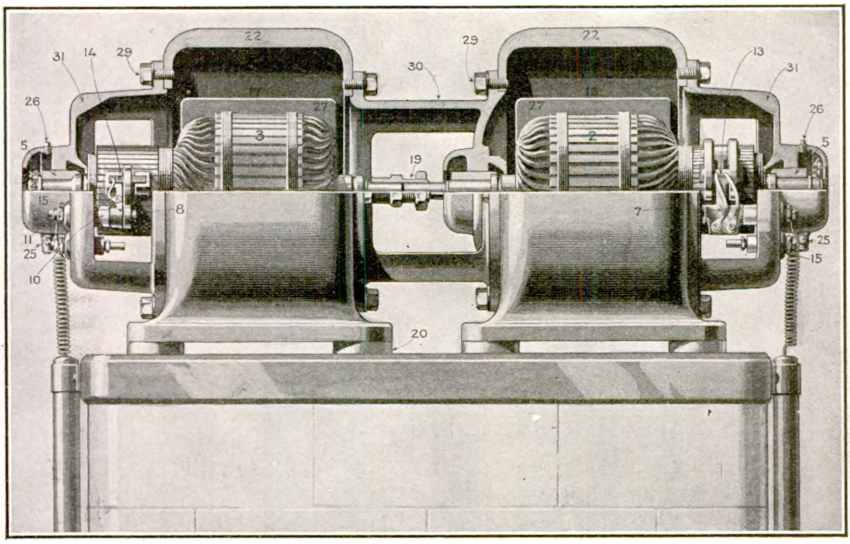


Fig. 6–34.—C. B. TELEPHONE SYSTEM, MOTOR GENERATOR.

Part No.	Name.	Reference No.
1	Armature, complete	
2	Armature, dynamo	2
3	Armature, motor	3
4	Box, journal, set screws for	4
5	Boxes, journal, complete	5
6	Brush holder, dynamo, left	
7	Brush holder, dynamo, right	7
8	Brush holder, motor, left	8
9	Brush holder, motor, right	
10	Brush and terminal stud	10
11	Brush and terminal stud, nut for	11
12	Brush and terminal stud, brass washer for	
13	Brushes, dynamo	13
14	Brushes, motor	14
15	Bushing, porcelain	15
16	Coil, field, dynamo	16
17	Coil, field, motor (state voltage)	17
18	Connection, drawing	
19	Coupling	19
20	Feet, rubber	20
21	Generator end, complete	21
22	Motor end, complete	22
23	Name plates	
24	Name-plate screws	
25	Oil cock, ⅛-inch	25
26	Oil-well plugs	26
27	Pole shoe	27
28	Pole-shoe screw	
29	Shield cap, screws for	29
30	Shield, connecting	30
31	Shield, front	

With small installations, where the storage battery is charged from a direct current lighting main through lamps, two separate storage batteries will invariably be installed, for, if telephone switchboard is connected to storage battery being charged, the electric lighting circuit is in electrical contact with all telephone lines radiating from telephone switchboard, a condition which should never be permitted.

Where the post lighting system is of alternating current the storage battery must necessarily be charged by means of a motor generator or suitable

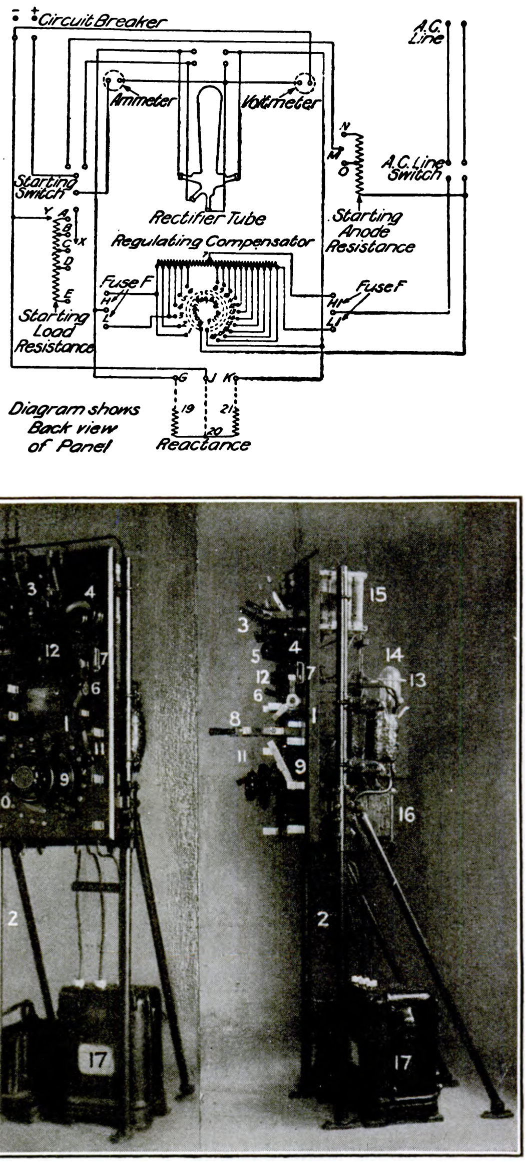


Fig. 6-35.—C. B. TELEPHONE SYSTEM, MERCURY ARC RECTIFIER.

(See fig. 6–35.)

Part No.	Name.	Reference No.	Part No.	Name.	Reference No.
1	Panel, control	1	10	Switch, 11-point (controlled by hand-wheel)	10
2	Panel, control, supporting frame for	2	11	Fuse clip, with fuse, S. P. D. T	11
3	Circuit breaker, C. G. type	3	12	Handwheel for tube holder	12
4	Ammeter	4	13	Tube holder	13
5	Voltmeter	5	14	Tube, rectifier	14
6	Switch, S. P. D. T., combined starting and load	6	15	Resistance, starting load	15
7	Switch, S. P. S. T. (auxiliary), for starting anode circuit	7	16	Resistance, starting anode	......
8	Switch, D. P. S. T., for A. C. line	8	17	Compensator, regulating	16
9	Switch, 6-point (controlled by hand-wheel)	9	18	Reactance, A. C. series	17
			19	Transformer, insulating	......

current rectifier. The former is the standard method, and in listing material for a post telephone system information must be furnished concerning the available current, which will embody the following: Voltage, number of phases, and number of cycles. Figure 6–34 shows the construction of the motor generator except that the one shown is equipped with a direct-current motor.

Figure 6–35 shows the mercury arc rectifier which has been furnished in special cases.

POWER SWITCHBOARDS.

Signal Corps specification No. 519 relates to telephone power switchboards. There are five types, in order that all varying conditions can be met. Figure 6–36 shows the type No. 1, and figure 6–37 shows the type No. 4. With type No. 1 the batteries are charged by means of lamp resistance, and with the type No. 4 a motor generator is used for charging the battery. These panels are intended for installation about 18 inches from the wall, but their supporting frames are so constructed that they do not have to be braced to wall, consequently they may be placed any distance desired.

It may be necessary to install between the post electric-lighting circuit mains outside of administration building and power switchboard two additional conductors, for the reason that the electric-lighting mains to the building may be of such size that they would not be capable of carrying the excess current necessary for charging the storage batteries, or they may be of such size and length that the excess current would occasion such drop in voltage that the electric lights in the administration building would be dimmed. Should the installation of the above-mentioned leads be resorted to, it is desirable to enter the building by means of duplex power cable in underground conduit. The cable should terminate in building at a fuse block which should be connected with a knife switch. From knife switch leads should be connected with watt-hour meter before terminating at power switchboard.

Where alternating current power circuits are contained in iron conduits care must be taken to install both wires in the same conduit and to have the conduit grounded.

The watt-hour meter, knife switch, and fuse block referred to above will be supplied by the Signal Corps and, together with material for their installation, should appear in estimate of apparatus necessary. The fuse block and knife switch should be inclosed in a metal box or, as a substitute, a wooden box lined with asbestos. Electric current consumed in charging Signal Corps storage batteries installed in connection with post telephone systems at interior posts is chargeable to Signal Corps appropriations if obtained from a commercial source.

Figure 6–33 illustrates an installation of the central office apparatus for a small system, where direct current is available and where one room only can be obtained.

With this arrangement the leads from the switchboards and the post power should be brought up from the floor in loricated conduit fastened to the wall, even with the bottom of the panel; from this point the lead sheath is removed

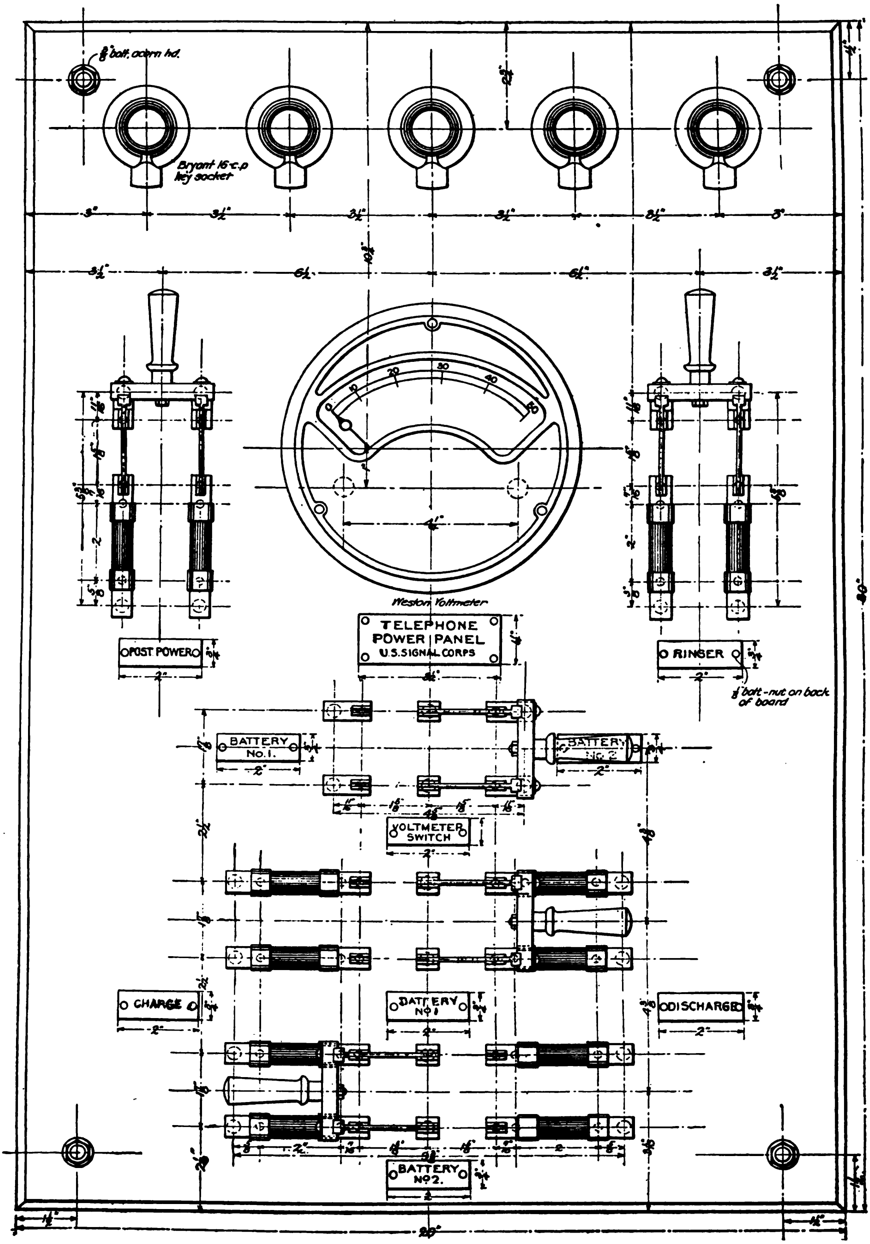


Fig. 6–36.—C. B. TELEPHONE SYSTEM, POWER SWITCHBOARD, TYPE NO. 1.

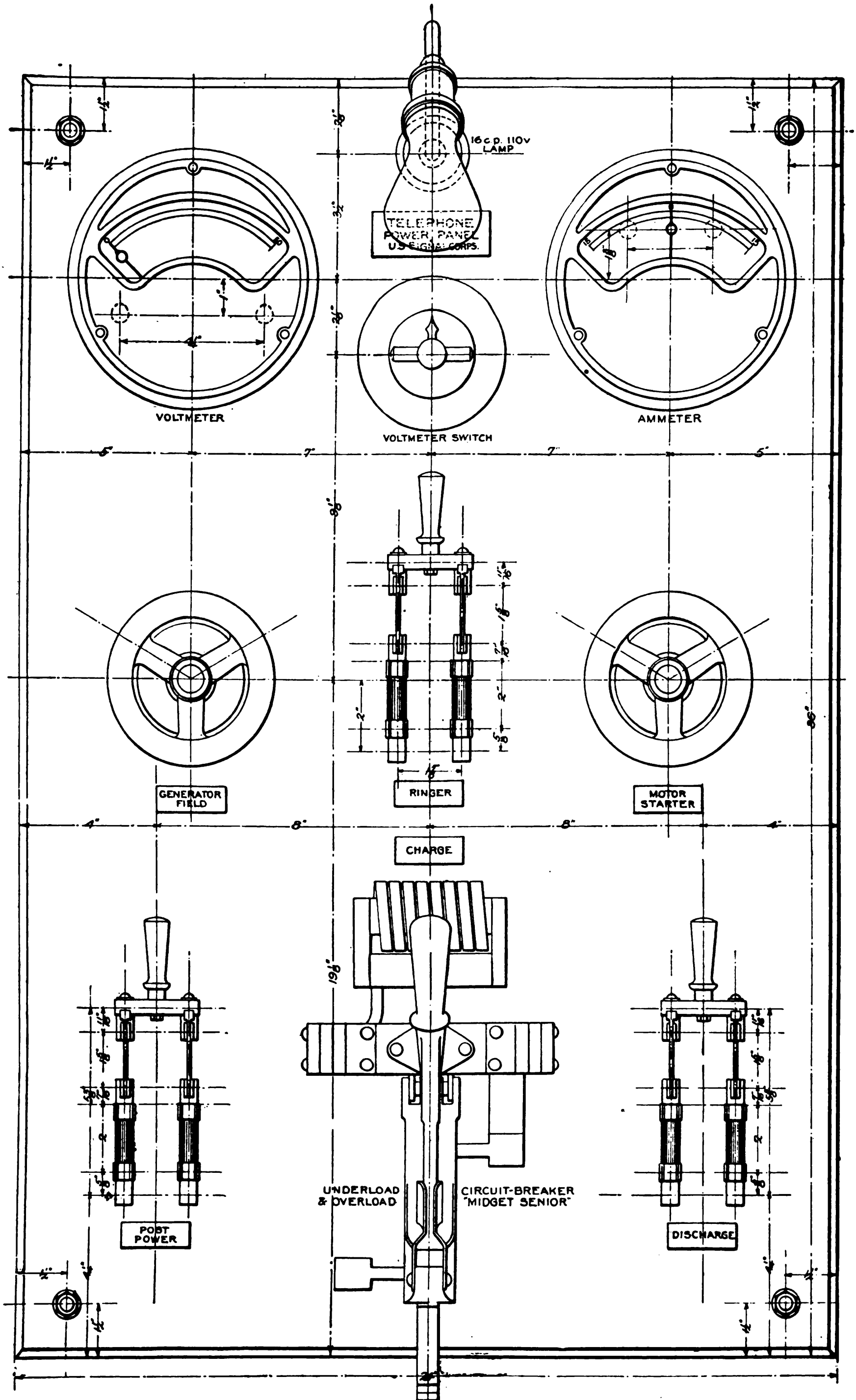


Fig. 6–37.—C. B. TELEPHONE SYSTEM, POWER SWITCHBOARD, TYPE NO. 4.

and the wires are carried over to the connecting lugs on the rear of panel. The exposed parts of the leads should be painted thoroughly with preservative paint. If the storage battery cabinet is near by, the leads can be extended directly to it; but if any considerable distance separates these apparatus their battery leads should be lead down to the floor and then to the battery cabinet in the same manner as they are lead to the panel. As previously stated, lead-covered cable should be used for the leads, the lead sheath being cut back at the end for connections. Complete instructions for installing and applying initial charge to storage batteries appear in chapter 1 of this manual.

RINGING APPARATUS.

Ringing apparatus for furnishing ringing current for calling is sometimes furnished with a large installation. When this apparatus is used it is only necessary for the operator at switchboard to depress proper ringing key in order to call party desired, thereby obviating the manual operation of the switchboard generator. The change from dynamotor to switchboard magneto and vice versa is quickly accomplished by means of special key at switchboard. The ringing dynamotor has been furnished by the Signal Corps in most instances.

Telephone-power equipment is sometimes utilized for furnishing primary current for the dynamotor. The current strength required for these sets furnished to date is approximately 2 amperes, the motor feature of dynamotor being designed for either 24-volt or 30-volt circuit. An 80-volt alternating current of approximately $16\frac{2}{3}$ cycles is delivered at ringing keys of telephone switchboard by the dynamotor. Figure 6–38 illustrates this apparatus.

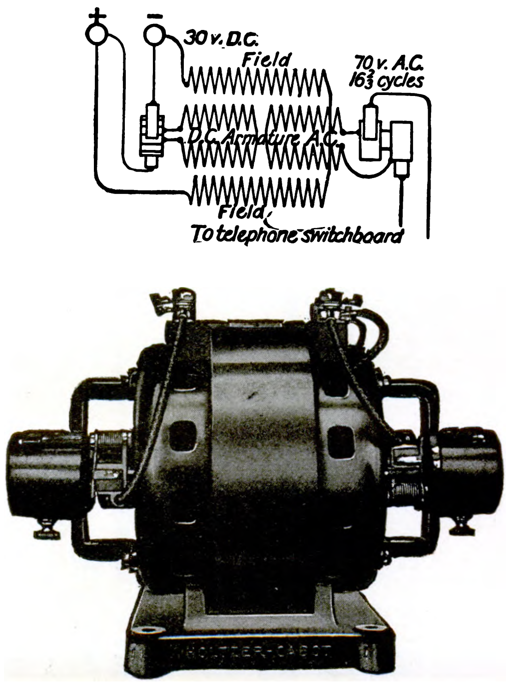


Fig. 6–38.—C. B. TELEPHONE SYSTEM, DYNAMOTOR, RINGING.

The advantage in having dynamotor operate from these voltages instead of the post-power voltage is that, should the post power be cut off, the dynamotor can be operated by the storage battery while ordinarily the storage battery charging circuit could be used to operate the dynamotor. The latter method is usually inefficient, and where it is contemplated to furnish a dynamotor, using telephone-power equipment for operating it, it is advisable to furnish storage battery of such capacity that the dynamotor may be operated thereby without too frequent charging. It is particularly desirable to operate the dynamotor by means of telephone-power equipment at places where power plant supplying post power is not operated during daylight, a condition that commercial telephone companies frequently have to meet. Under such conditions an apparatus termed "pole changer," which is operated by primary batteries, is sometimes supplied for furnishing ringing current.

Where there is a reliable and continuous source of electric power it may be advisable to operate the dynamotor by means of this power. If power be direct current, the motor feature of dynamotor must be designed for the voltage of the circuit available. If power be alternating current, a motor generator is supplied. Thus, it will be seen that conditions should be carefully surveyed before deciding upon the manner of furnishing ringing current.

TELEPHONES.

Telephones used in connection with post-telephone systems are of the commercial standard type, and are fully described in chapter 3 of this manual.

RECORDS OF AN INSTALLATION.

It is a well-known fact that in no branch of the industrial field are records of such great importance as those pertaining to electrical installations. While the development of instruments and methods employed in electrical science have reached a point where little time is lost in locating faults and in repairing or making operative an electrical circuit that becomes inoperative, accurate records facilitate to a marked degree such repairs, and are a great convenience to those vested with maintenance of the systems.

The Signal Corps requires that upon completion of installation of a post-telephone system, a complete and accurate record be prepared. This record consists of standard Signal Corps forms, appropriately accomplished, and drawings illustrating routing of cables, connections, cross connections, and special circuits employed. The drawings should be made by means of waterproof ink on tracing cloth. When it is impracticable to make these drawings at post where installation is made, the data should be forwarded by person in responsible charge of the installation to the Departmental Signal Officer of department in which post is located. The Department Signal Officer will have the drawings made, using the data furnished as a guide, if facilities are available in his office. If impracticable to make the drawings in the office of the Department Signal Officer, the data should be forwarded to the Chief Signal Officer of the Army with request that the drawings be made.

When drawings have been approved, complete sets (prints of tracings) shall be filed as follows: One in office of Chief Signal Officer of the Army; one in office of Department Signal Officer, and one or more at office of post signal officer. In addition, at least one copy of drawing shown under subheading "a" appearing later in this chapter shall be transmitted to the local post quartermaster, that he may be familiar with location of Signal Corps cable and conduit system. If there are facilities for changing the drawings (tracings) and for

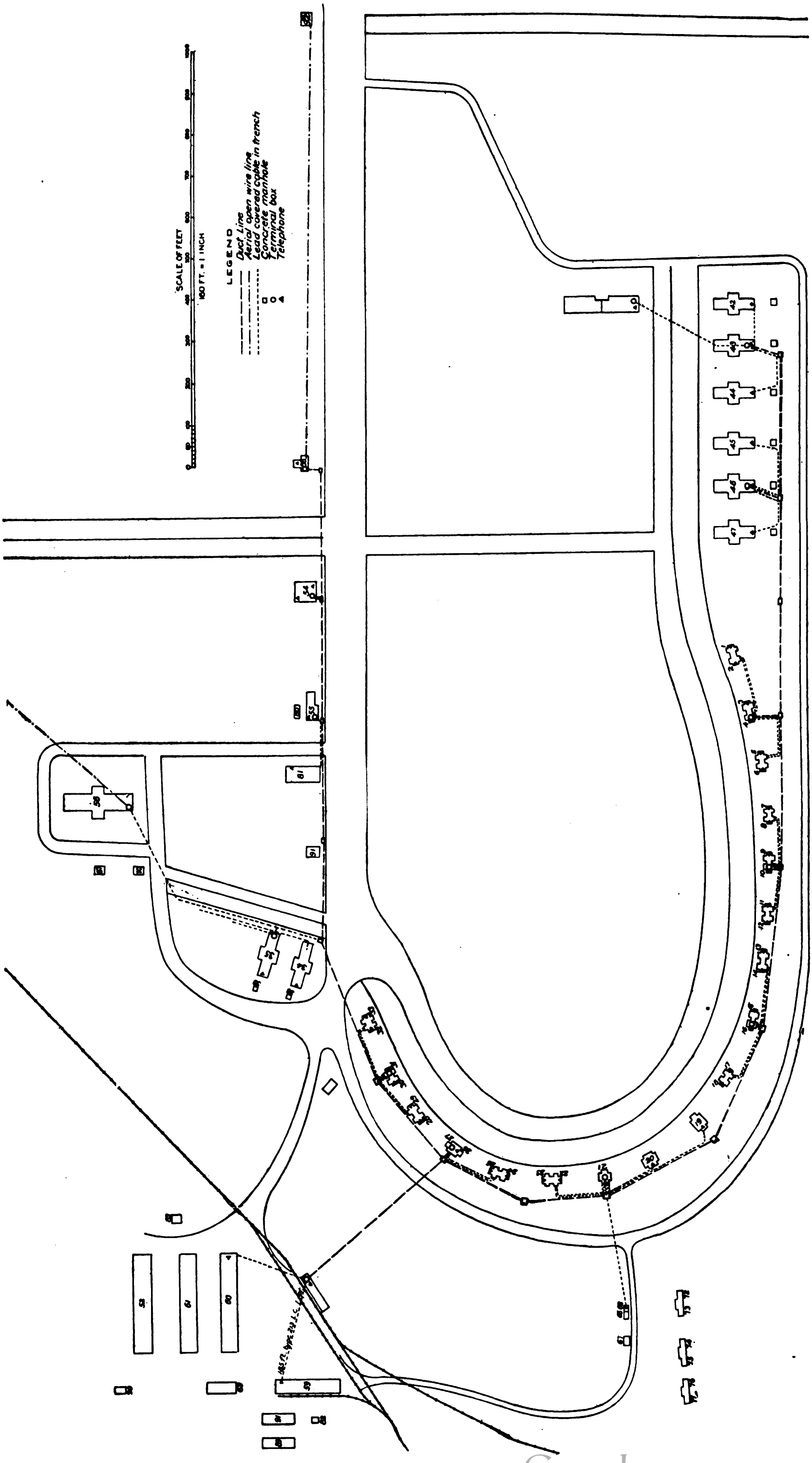


Fig. 6–39.—TELEPHONE SYSTEM, RECORD, ROUTING OF LINES AND LOCATION OF STRUCTURES.

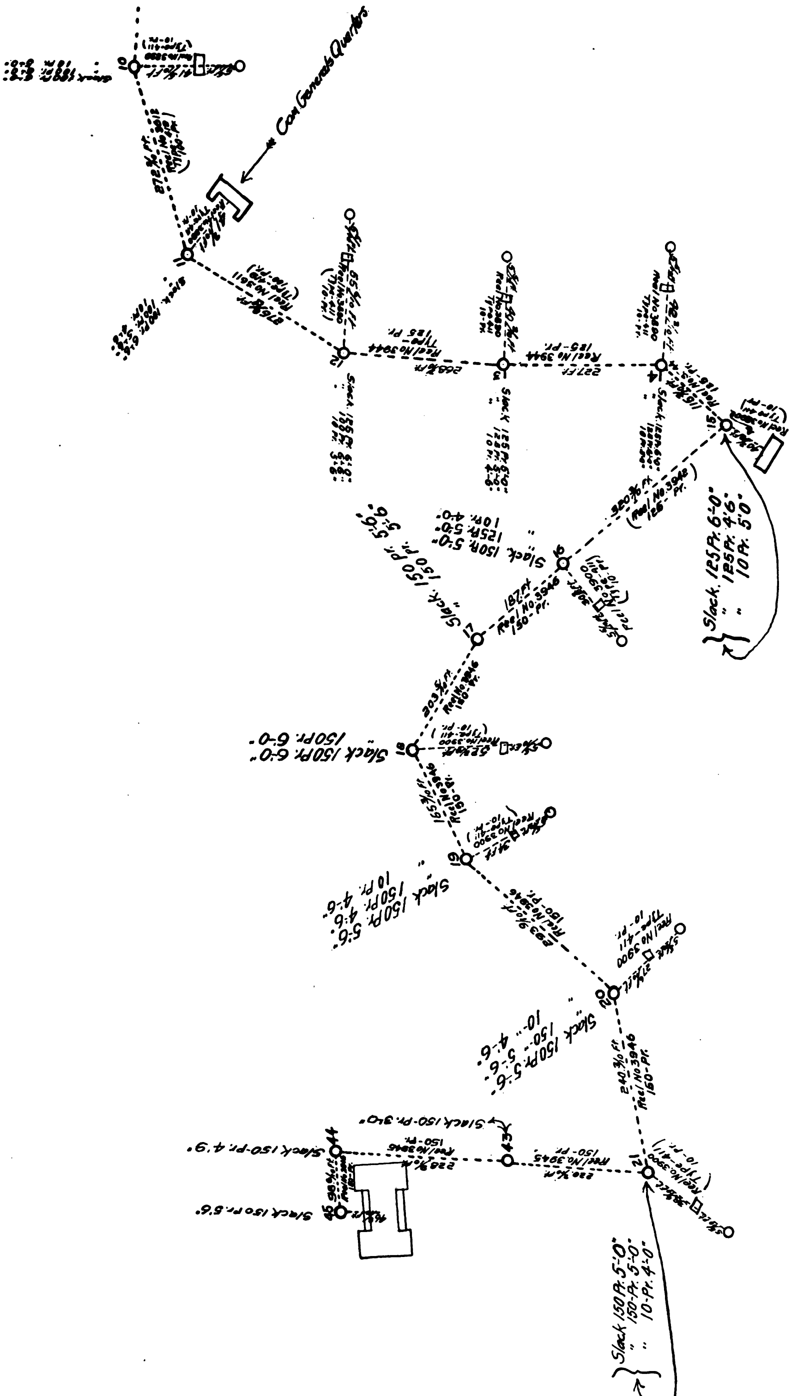


Fig. 6-40.—TELEPHONE SYSTEM, RECORD, CABLE SPLICES AND LENGTHS.

making prints in the office of the Department Signal Officer, the tracings will be filed in that office, otherwise they will be filed in the office of the Chief Signal Officer of the Army.

The upkeep of these records is of utmost importance. All authorized changes, regardless of their apparent insignificance, should be recorded. It is the duty of post signal officers to see that all modifications of the original system are reported to the Department Signal Officers. Upon receipt of satisfactory data, showing authorized modifications of an installation, Department Signal Officers will take steps to have the drawings (tracings) corrected, and each authorized office furnished with corrected copy, at the same time advising all recipients that the forms or drawings supersede similar ones previously furnished.

Component parts of the record are enumerated below, and the items as described should be strictly adhered to in order that post signal officers ac-

	Strip #1 (Cable 38)	Strip #2 (Cable 38)	Strip #3 (Cable 39)	Strip #4
1	3-12	4-2	1-7	2-4 (Cable 35)
2	2-10	4-3	1-8	2-1 (Cable 33)
3		Open	1-5	2-2 (Cable 34)
4	2-12	4-1	1-6	
5	3-3	2-11		
6	3-4			
7	3-1			
8	3-2			
9				
10		1-2 (I.W.)		
11		2-5 (I.W)		
12		1-4 (I.W.)	1-1 (I.W.)	

	Strip #1	Strip #2	Strip #3	Strip #4
1	Officer's Qtrs Bldg 53A	Offrs Qtrs Bldg 51	Offrs Qtrs Bldg 21	Offrs Qtrs Bldg 52
2	Offr's Qtrs Bldg 53B	Laundry	Offrs Qtrs Bldg 22	Offrs Qtrs Bldg 51
3			Offrs Qtrs Bldg 29	Laundry
4	Offr's Qtrs Bldg 53C	Offrs Qtrs Bldg 52	Offrs Qtrs Bldg 30	
5	Offrs Qtrs Bldg 29	Offrs Qtrs Bldg 53D		
6	Offrs Qtrs Bldg 30			
7	Offrs Qtrs Bldg 21			
8	Offrs Qtrs Bldg 22			
9				
10		Offrs Qtrs Bldg 53B		
11		Offrs Qtrs Bldg 53D		
12		Offrs Qtrs Bldg 53C	Offrs Qtrs Bldg 53A	

Fig. 6-41.—TELEPHONE SYSTEM, RECORD, CONNECTIONS AND CROSS CONNECTIONS OF CABLE CONDUCTORS.

customed to the record at one post will be familiar as far as practicable with the records at another.

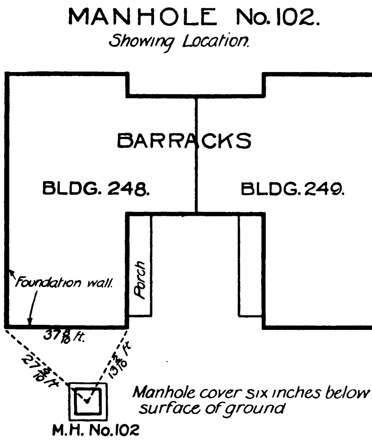


Fig. 6–42.—TELEPHONE SYSTEM, RECORD, LOCATION OF MANHOLES.

(*a*) Drawing, map to scale, showing routing of all Signal Corps cables and aerial lines and the location of all substations, terminals, and all principal structures. (See fig. 6–39.)

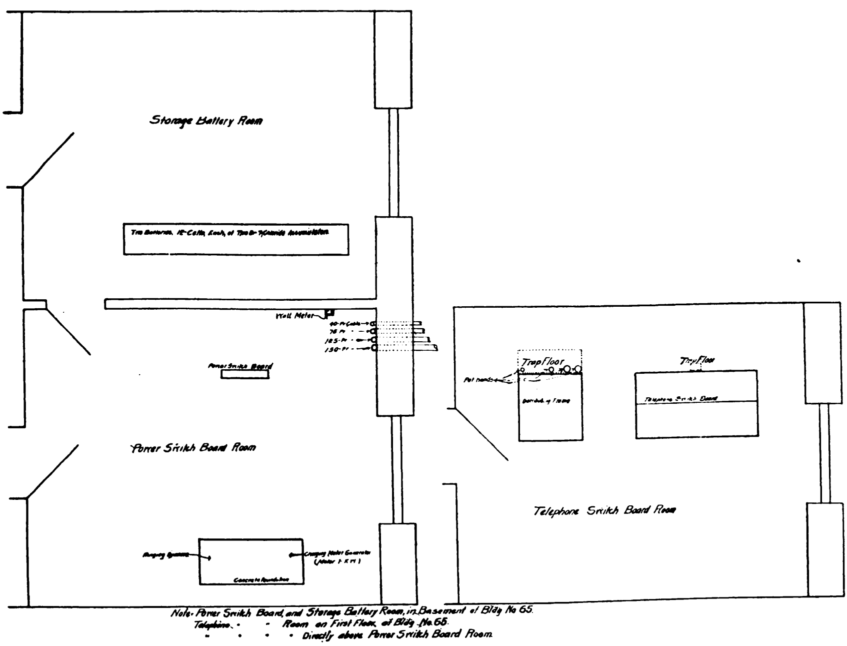
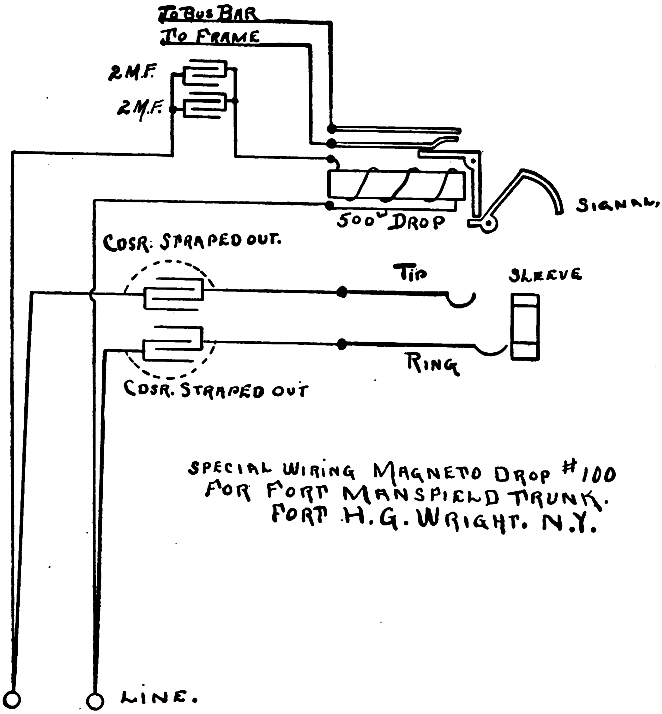


Fig. 6–43.—TELEPHONE SYSTEM, RECORD, ARRANGEMENT OF POWER EQUIPMENT.



Special Wiring Drop #59 For New London Trunk.
Fort HG. Wright. N.Y.

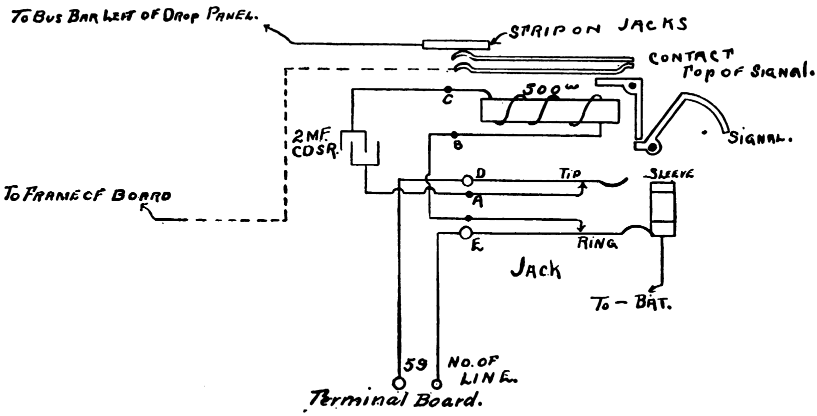


Fig. 6–44.—TELEPHONE SYSTEM, RECORD, SPECIAL CIRCUITS.

(*b*) Drawing, diagram, not necessarily to scale, for each post, showing the distances between all manholes and the distance between terminal manholes and end of each cable terminating in adjacent stretch. This diagram should show slack of each cable in each manhole, as well as location of splices in each cable. In indicating slack it may be necessary at times to have such indication a minus quantity; this is due to the fact that the amounts entered should be the difference between a straight line through manhole and actual path taken by cable in the manhole. Diagram should also show in tabulated form the number, the type, and the total length of each cable. (See fig. 6–40.)

Signal Number	Cable Strip Number in Telephone Term Cabinet	Arrester No. in Tel Term. Cabinet	Cable No. 11	Cable No. 12	Cable No. 6	Location of Inst.	Type of Instrument	Serial Number of Inst.	
0	1		1						
1	2		2			1st. Officers Qrs.	C. B. Wall	3208	
2	3		3			2nd " "	" " "	3209	
3	4		4			3rd. " "	" " "	3252	
4	5		5			4th. " "	" " "	3250	
5	6		6			Hospital	" " "	3251	
6	7		7			Elect. Sgt. Qrs.	" " "	3238	
7	8		8			Barracks	" " "	3313	
8	9		9			Guard House	" " "	3210	
9	10		10			Post Exchange	" " "	3239	
10	11		11						
11	12			1		Qr. Master Off.	C. B. Wall	3181	
12	13			2		Commissary	" " "	3182	
13	14			3		Ord. Off.	" " "	3183	
14	15			4		Temp. Barracks	Comp Wall	6634	
15	16			5		Sergt. Mjrs. Off	C. B. Wall		
16	17			6		Adjutants Off.	C. B Desk		
17	18			7		C. O. Off.	C B "		
18	19			8		Arty. Engr. Off	C. B Wall	3231	

Fig. 6–45.—TELEPHONE SYSTEM, RECORD, CONNECTIONS, AND OTHER DATA.

If the data enumerated under this heading can be shown on map referred to under heading "a" without crowding the entries it may be done, thereby eliminating additional tracing.

(*c*) Drawing, not necessarily to scale, of each terminal box, submarine terminal box, junction box, distributing frame, and arrester cabinet showing the location of conductors of all cables terminating at that point, all cross connections, the use of each circuit, and all spare conductors. (See fig. 6–41.)

(*d*) Drawing, showing exact location of each manhole if they be of the type having cover below surface. Measurements shown should be between permanent substantial construction, such as masonary foundations of structures, if possible, and manholes. (See fig. 6–42.) If desired a number of these may be made on one sheet.

(*e*) Drawing, not necessarily to scale, showing arrangement of power equipment. This is not necessary with local battery systems (see fig. 6–43). A

Signal Corps drawing of power switchboard may be added to show circuits if it is applicable.

(*f*) Drawing, not necessarily to scale, showing each special circuit if there be any not shown in this manual. (See fig. 6–44.)

(*g*) Drawing, diagram showing post-telephone connections and other important data. (See fig. 6–45.)

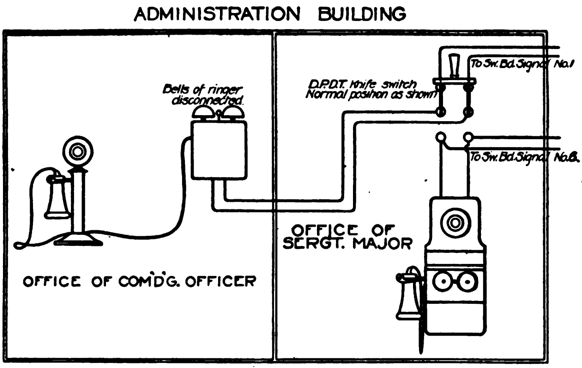


FIG. 6–46.—TELEPHONE SYSTEM, RECORD, SPECIAL ARRANGEMENT.

(*h*) Miscellaneous drawings and diagrams. Under this heading should be included drawings or diagrams illustrating any part of the installation not covered by the above and which the engineer in responsible charge of installation believes should be elucidated. (See fig. 6–46.)

SIGNAL CORPS FORMS.

(*i*) Form No. 261 (cable record) should be accomplished in triplicate for each cable of the system.

(*j*) Form No. 211 (report of inspection of Signal Corps equipment) should be accomplished in triplicate. As the name implies, Form No. 211 is a form used in recording results of inspection. Inasmuch as this form requires a great amount of information that can be much more readily secured at time of installation of apparatus, it has been made a part of the standard record.

(*k*) Form No. 209 (semiannual report of post telephone equipment) should be accomplished in triplicate. This form also requires information that should be supplied upon completion of an installation.

(*l*) Form No. 279 (summary of cost of an installation) should be accomplished in duplicate, one copy for office of Chief Signal Officer of the Army and one for office of Department Signal Officer.

(*m*) Form No. 264 (report on the progress of installations). During the progress of installation of a post telephone system, where the work involved requires more than one month to complete, this form, accomplished in duplicate, will be forwarded by person in responsible charge of work to the Department Signal Officer. These forms will be forwarded at the end of each calendar month, and upon completion of the work if such completion does not occur on last day of calendar month. One of these forms will be filed in office of Chief Signal Officer of the Army and one in office of the Department Signal Officer.

(*n*) Form No. 210 (monthly report of employees at large). The person in responsible charge of installation will collect at the end of each calendar month a single copy of this form, duly accomplished, from each electrical engineer, assistant electrical engineer, and electrical assistant engaged on the work, and will forward these forms, together with one copy of the same form accomplished by himself, if he be a civilian employee of the Signal Corps, to the Department Signal Officer of the department in which he is operating. This form is for the files of the office of the Chief Signal Officer of the Army.

Maintenance of Post Telephone Systems.

SUMMARY OF FAULTS THAT ARE MOST LIKELY TO OCCUR AND AN ENUMERATION OF CAUSES.

LOCAL BATTERY INSTRUMENTS.

(*a*) *L. B. station can not ring another station.*—Defective apparatus at other station. Broken wire in either instrument. The coiled spring on magneto driving shaft broken. Open circuit in magneto windings. Contact piece at end of magneto armature shaft bent or broken. Open, crossed, or grounded lines external to instrument. If any of the latter faults exist, unless line is short circuited the home station should be able to ring its own ringer.

(*b*) *L. B. station does not receive a ring from another station.*—Distant instrument defective. Home station ringer out of adjustment or permanent magnet weak. Open circuit in ringer magnets or broken wire in ringer circuit. Failure to operate of magneto automatic cutout. External line open or short circuited.

(*c*) *L. B. station can not transmit speech to distant station.*—Distant station apparatus defective. Hook switch contacts out of adjustment. Local battery weak or open circuit in primary circuit, including winding of induction coil. Open circuit in secondary winding of induction coil, receiver, receiver cord, or instrument wire. Packed or defective transmitter. External line open or short circuited.

(*d*) *L. B. station can not receive speech from distant station.*—Distant station apparatus defective. Hook switch contacts out of adjustment or broken. Defective receiver, such as open circuit in cord, windings, or diaphragm distorted. Open circuit in secondary winding of induction coil or instrument wire. External line open or short circuited.

COMMON BATTERY INSTRUMENTS.

(*a*) *C. B. station can not signal switchboard operator.*—Defective central station apparatus. Common battery cut off. Hook switch contacts out of adjustment or broken. Open circuit in primary winding of induction coil, transmitter circuit, or instrument wiring of these circuits. Open or short circuit in external line.

(*b*) *C. B. station holds operator's signal when hook is down.*—Short circuited condenser. Hook switch contacts out of adjustment. External line short circuited.

(*c*) *C. B. station does not receive a ring.*—Defective central station apparatus. Home station ringer out or adjustment or permanent magnet weak. Open circuit in condenser. Open circuit in ringer magnets, or broken wire in ringer circuit. External line open or short circuited.

(*d*) *C. B. station can not transmit speech.*—Defective central station apparatus. Common battery cut off. Hook switch contacts out of adjustment or broken. Open circuit in primary winding of induction coil, transmitter circuit, or instrument wiring of these circuits. Packed or defective transmitter. External line open or short circuited.

(*e*) *C. B. station can not receive speech from distant station.*—Distant station apparatus defective. Hook switch contacts out of adjustment or broken. Defective receiver, such as open circuit in cord, windings, or diaphragm distorted. Open circuit in secondary of primary winding of induction coil or instrument wire. Open circuit in transmitter or transmitter cord. External line open or short circuited.

(*f*) *Speech at distant station is indistinct, scratching or grating noise in receivers.*—Loose connections or battery too strong. (This may be noted during charging of telephone storage battery.) Damaged or broken receiver cord.

NOTE.—In common battery transmission, if the line resistance is excessive transmission is weakened. Six miles of cable with conductors 36 mils diameter is considered the limit of common battery supply for efficient conversation.

TELEPHONE SWITCHBOARD TROUBLES.

SUMMARY OF FAULTS WHICH ARE MOST COMMON.

(*a*) *Common battery switchboard, visual signal is feeble.*—This indicates a poor adjustment in the signal armature, low battery, or high line resistance.

(*b*) *Common battery switchboard, signal is irregular.*—This indicates loose connection either in the switchboard, switchboard cabinet, or in the external circuit. May be due to defective jack contacts.

(*c*) *Common battery switchboard, signal will not operate.*—Weak battery. Broken wire in either internal or external circuit. Signal short circuited or signal badly out of adjustment.

(*d*) *A grating noise noticed when plug of connecting cord is inserted in jack.*—Voltage of battery too high or partial open circuit in the connecting cord.

(*e*) *Cross talk.*—If the system is free from cross talk when installed and trouble does not exist in the exterior system, cross talk that may develop is probably due to the sticking of the listening-key contacts in switchboard, thus bridging two or more lines together. Moisture in terminal boxes or moist wire forms is another condition which sometimes causes cross talk.

(*f*) In lamp line switchboards or in visual signal switchboards equipped with lamp supervisory signals the first step should be to examine the relays in the event of switchboard signal trouble.

With any switchboard where it is determined that a fault exists in the central station the proper procedure is to first examine the heat coils pertaining to the line in trouble. Having determined that the trouble exists within the switchboard, it is a simple matter to localize the fault if a person is thoroughly familiar with the circuits of the switchboard.

If the repair of a defective switchboard circuit is urgent, it may be advisable to transfer the incoming line to a signal not in use, advising the switchboard operator of such action and repairing the defective circuit as soon as practicable thereafter.

In cord switchboards if the drop does not fall, test first for continuity of circuit and then see if the pivots are loose. If the pivots are loose the armature will frequently stick and fail to release the shutter.

If when a ring comes in more than one drop falls it may be due to a cross in the lines just outside of the board, or else on the lightning strip to which these lines are connected. This can be readily cleared by inspection. The trouble may be due to the fact that the contacts on the magneto side of some one of the ringing keys are not broken when the key is in a normal position.

When it is discovered that a pair of cords do not perform their proper function they should be tested for an open or for a "cut-out."

A frequent cause of trouble in the jacks is due to the fact that persons will stick pens or pins in them and break off the points, short-circuiting the springs. The only way to discover this is by thorough inspection of the jacks. To see whether the contacts in the ringing and listening keys break in the proper manner the part of the board containing them should be placed between the light and the eye of the inspector. By looking at the keys against the light and opening and closing them it will be discovered whether the contacts break properly or not. Trouble may frequently be removed from the cord circuit by cleaning the tip and sleeve of the plug with crocus cloth. When a switchboard is new and first placed in service particles of metal are frequently found in the jacks, and the board can be cleaned by using a hand bellows and blowing out all of the jacks thoroughly.

The accepted method of cleaning key contacts or mechanically testing for opens is by putting a strip of hard-surfaced paper between contacts when keys are open, closing the keys, and withdrawing it. If the key does not make a firm contact the paper will be easily withdrawn, and this trouble can be eliminated by adjusting the key. If it does make a firm contact, withdrawing the paper will clean off any dirt that may be on the contact.

Drops may be tested by using the short-circuiting key in the center of the lower panel of the telephone switchboard in connection with the test jack. Plug the defective drop into the test jack and press the button. If the drop operates freely it should be considered satisfactory.

CHAPTER 7.

SMALL-ARMS TARGET RANGE SIGNALING SYSTEMS.

Paragraph 262 of "Small-Arms Firing Manual, 1913," reads as follows:

Classes.—There are two classes of ranges: Class A ranges, which are more or less limited in extent and which are equipped for known distance practice; class B ranges, which are of extended area and diversified terrain, and which are used for combat firing.

The Signal Corps furnishes and installs material and apparatus for communication for class A ranges referred to above. Inasmuch as the class B ranges are often temporary in both arrangement and location, no fixed signaling system for them can be devised. The Signal Corps has furnished apparatus and material for establishing communication for such ranges, the installation being made by detachment of troops.

Class A ranges only are considered in the following:

The system of communications to be furnished target ranges depends on the type of range, its size and importance, and upon local conditions, which vary for each case. Among such local conditions may be mentioned the character of the soil and the necessity for using the range for other purposes, such as drill, etc.

In general the systems for class A ranges may be divided into three types, as follows:

Type 1.—This system is applicable to all types of ranges and provides for telephonic communication only. The circuits of this system comprise a telephone line from extreme end to end of the range with outlets at each firing line to which a portable telephone may be connected by means of a flexible cord and plug. The line is preferably laid underground in trench or conduit, lead-covered or lead-covered and armored, rubber-insulation, single-pair cable being used for this purpose. The telephone used is the standard camp telephone or obsolete field telephone fitted with cord and plug for attachment to outlet. Where necessary, the telephone may be placed in a portable shelter box.

This type of system is used on small or unimportant ranges where the expense of a more extensive system is not justified, or for provisional work where, on account of lack of funds or other causes, it is not possible to supply a more complete system.

Type 2.—This system of communication is applicable to targets in echelon only. It comprises the following communications:

(*a*) A telephone for every group of 10 firing points or less on line to telephone at butts.

(*b*) A push button at each firing point connected to the buzzer at the corresponding target.

(*c*) An annunciator at the butts of 200-yard, 300-yard, and 500-yard ranges, with a drop for each target of the respective ranges. Each drop may be actuated by associated strap key in rear of respective target.

(*d*) A master switch at each annunciator, by which all target buzzers may be operated simultaneously.

This system will be installed underground in trench or conduit, using paper insulation cable for longitudinal runs, and rubber-insulation, lead-covered, and armored cable (type 251) for the branches at the firing lines.

Type 3.—This system is for installation at target ranges having only one group of targets, the several ranges being obtained by placing the firing points behind each other. The equipment corresponds closely to the type 2, with such modifications as are necessary to adapt it to such arrangement. It provides the following communication:

(*a*) A telephone for every group of 10 firing points or less on line to telephone at butts.

(*b*) Push buttons at each firing point connected to a buzzer at the corresponding target.

(*c*) An annunciator with a drop for each target, which drop may be actuated by a strap key at associated target.

(*d*) A master switch at the annunciator by which all target buzzers may be operated simultaneously.

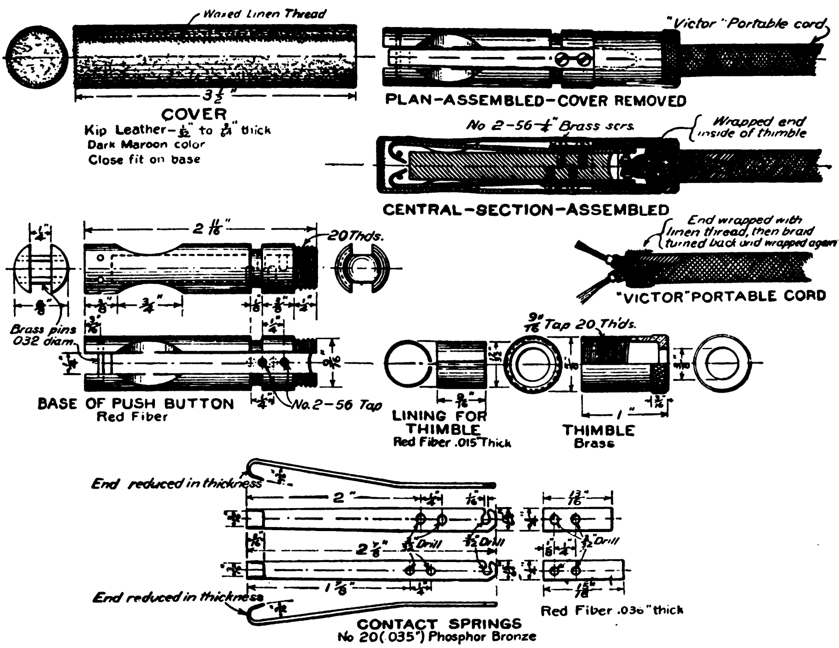


Fig. 7-1.—S. A. TARGET RANGE PUSH BUTTON.

This system will be installed underground, using paper insulation cable for runs requiring a large number of conductors, and type 251 cable for distribution, the same as for the type 2 system.

It will be noted that with the type 2 system the 200-yard, 300-yard, and 500-yard ranges are supplied with annunciator, master switch, and strap keys in addition to the other apparatus, and that the 600-yard, 800-yard, and 1,000-yard ranges are not supplied with that apparatus, although a buzzer is installed in rear of each target, making the latter a buzzer system while the former is a buzzer annunciator system.

The reason for this is that the annunciator, master switch, and strap key is apparatus used in connection with raising and lowering the targets promptly and simultaneously, an operation pertaining to rapid-fire practice. Rapid-fire practice is held only on ranges up to and including 500 yards.

The source of power for operating the buzzer system and also the buzzer annunciator system is 20 cells of No. 6 reserve type dry cells of battery (for description of cell see chap. 1) installed in distributing box upon two shelves provided for that purpose. The distributing box is described later in this chapter.

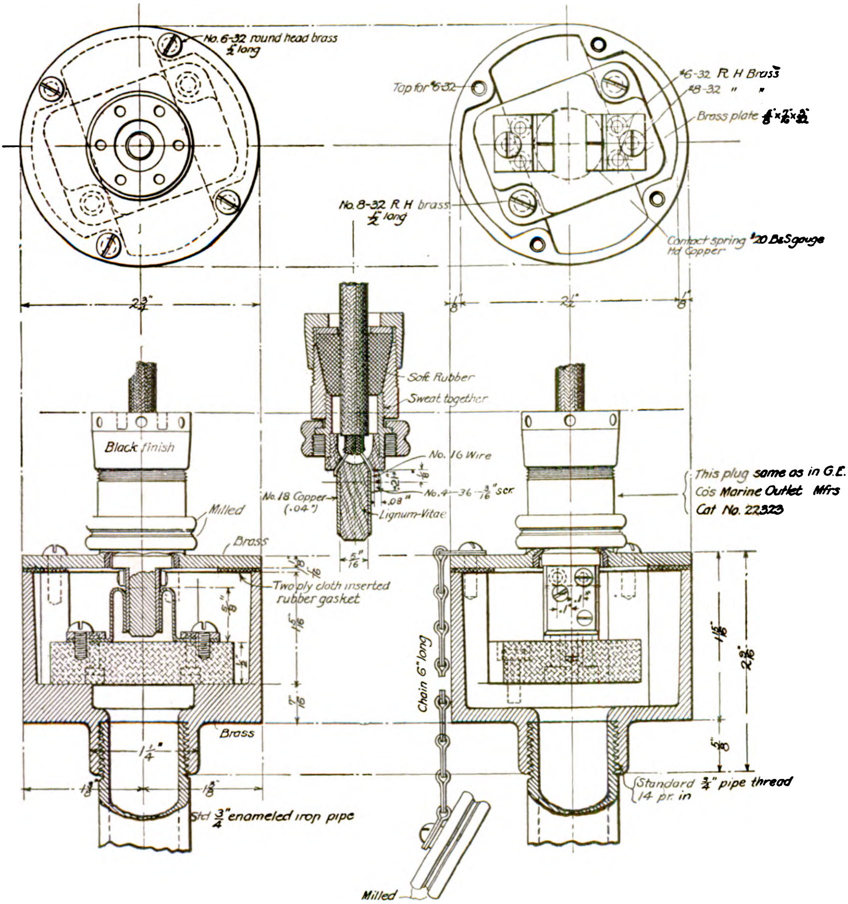


Fig. 7–2.—S. A. TARGET RANGE OUTLET BOX, ROUND PATTERN.

Each group of targets on the larger ranges is usually equipped with a small structure in rear and in proximity to parapet wall. This structure is used for storing targets and supplies and may be used for range officer's station during firing. At ranges where buzzer annunciator systems are installed the annunciator distributing box and master switch should be located in this structure if practicable. In some instances the Signal Corps has constructed a small frame booth in the form of a lean-to against parapet wall for housing this apparatus. The booth was equipped with a slide window on either side in order that range officer might observe the actions of men at targets. It was also equipped with a tight roof and door with substantial lock in order that when range was not in use contents of booth might be made secure.

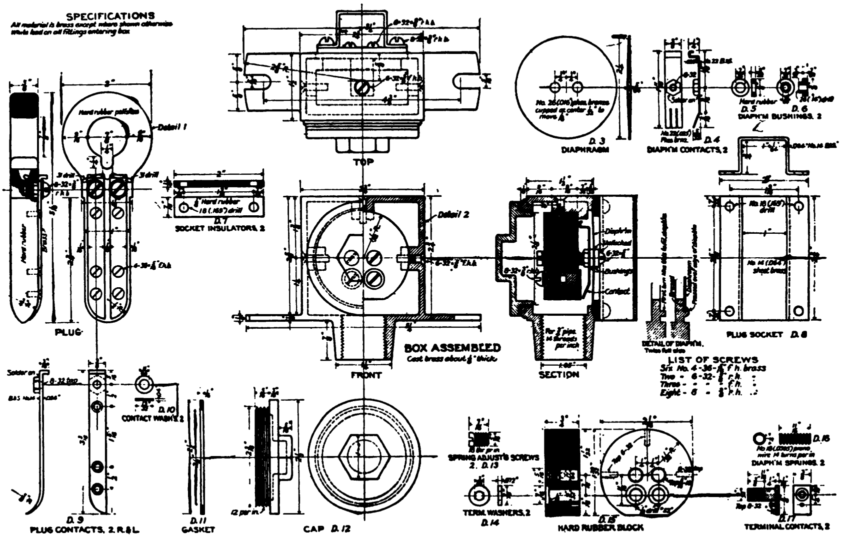


Fig. 7-3.—S. A. TARGET RANGE OUTLET BOX, 1915 MODEL.

The target range outlet boxes for the push-button attachments should be located approximately 10 feet in rear of each firing point, as scorers are required to be seated close to and in rear of the firing-point stakes.

The push-button attachments should be removed and stored in a dry room upon completion of each day's practice during inclement weather and when target practice is suspended for a period of days.

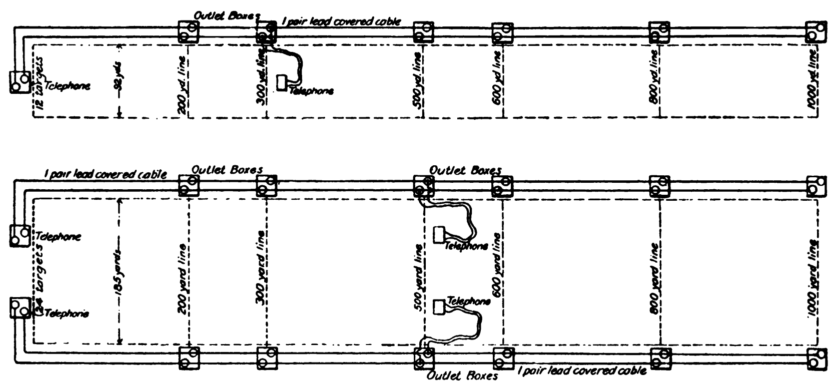


Fig. 7-4.—S. A. TARGET RANGE, TYPE NO. 1 SYSTEMS.

The push-button attachment consists of a two-conductor flexible cord, approximately 6 feet in length, equipped at one end with a specially designed push button that can be comfortably held in the hand. At other end the cord is equipped with a suitable plug adapted for attachment to permanently installed

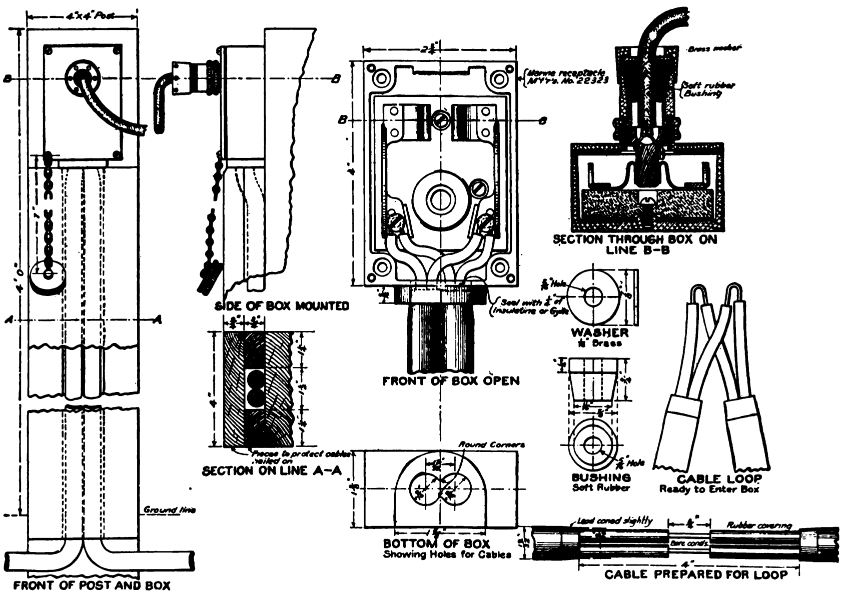


Fig. 7–5.—S. A. TARGET RANGE, TYPE NO. 1 SYSTEM, OUTLET BOX.

target range outlet boxes. The push button referred to is shown in figure 7–1, and the round-pattern target range outlet box with plug is shown in figure 7–2. These boxes have been more or less unsatisfactory, due principally to the fact that the screw cap covers are often not replaced when plug of push-button cord is withdrawn, thereby allowing moisture to enter the box.

Figure 7–3 shows an outlet box designed by the Signal Corps which is now being given a service test. With this box there is no screw cover to be removed or replaced in connection with the operation of inserting or withdrawing the plug. When plug is inserted in socket on outside of box, a thin metal diaphragm forming side of box is depressed. Two insulated contact pieces through diaphragm, which make contact with parts of plug to which conductors of cord are attached, are made to connect with suitable terminals of cable on inside of box by depression of diaphragm. It is therefore only necessary to remove plug when use of a particular outlet is completed. Removal of plug allows diaphragm to attain normal position, thereby breaking contact between insulated pieces through diaphragm and terminals of cable on inside of box. It can readily be seen that surface leakage of battery current, due to moisture on outside of box, is eliminated when plug is withdrawn.

For illustrating the various types of ranges and for showing the equipment furnished and the methods of its installation, type ranges are shown in the following figures. In future it will probably be found that in no case does the range exactly conform to any one of the types shown. It may be necessary, therefore, to modify the type scheme to make it applicable to any particular case.

Figure 7–4 shows the type 1 system as installed on a range equipped with 12 targets and as installed on a range equipped with 24 targets. Figure 7–5 shows the type of outlet box and manner of connecting it installed at each firing line, and figure 7–6 shows the construction of a portable box for protecting telephones used. In preparing lists of material for installation of a type 1 system, either the length of cords for connecting the portable telephones or width of range and number of targets must be stated.

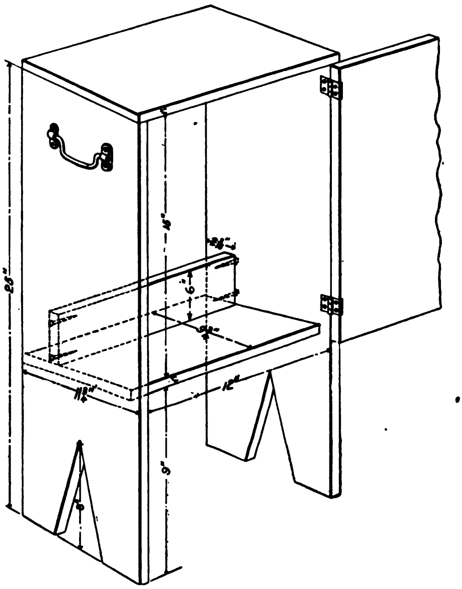


Fig. 7–6.—S. A. TARGET RANGE, TYPE NO. 1 SYSTEM, TELEPHONE BOX.

Figure 7–7 shows a type 2 system using one diminishing size cable laid diagonally across the range with taps to the various butts, while figure 7–8 shows separate cables used for each. For echelon ranges either of these methods or a combination of the two may be used, depending upon local conditions; however, whenever practicable, the method shown by figure 7–8 is preferred. The scale size of these illustrations is such that it is impracticable to show all apparatus.

Figure 7–9 shows a type 3 system. With this particular system the 200-yard firing points were not equipped with outlets but provision for such equipment was made, the necessary manholes on line of main cable having been provided.

Strap keys, annunciator, and master switch are provided for this type of range in order that standard communication for rapid-fire practice at the 200-yard, 300-yard, and 500-yard firing points will be available.

Figure 7–10 shows the method employed in installing the round pattern outlet boxes. Sewer flush pipes with cover are used to house the outlet box where is terminated the type 251 cable (1 pair lead covered and armored). A wrought-iron support for outlet box is fastened by means of machine screws to bell of sewer flush pipe. The type 251 cable enters the outlet box through a short length of three-fourth inch conduit threaded through support and into base of outlet box. The cable is sealed by filling the conduit, within which is terminated the sheaths of cable, with ozite or other approved moisture repellent

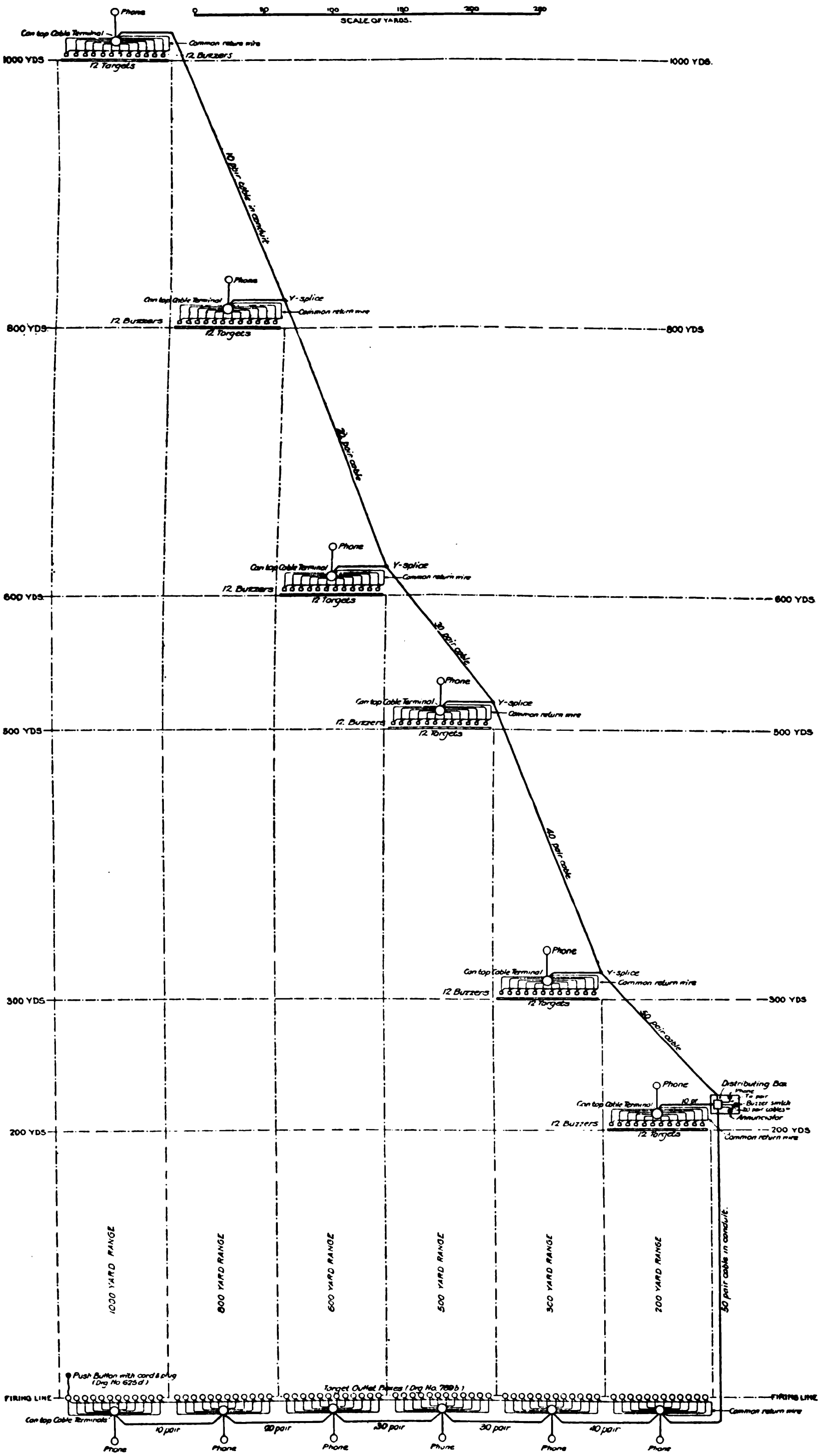


Fig. 7–7.—S. A. TARGET RANGE, TYPE NO. 2 SYSTEM, USING DIMINISHING CABLE.

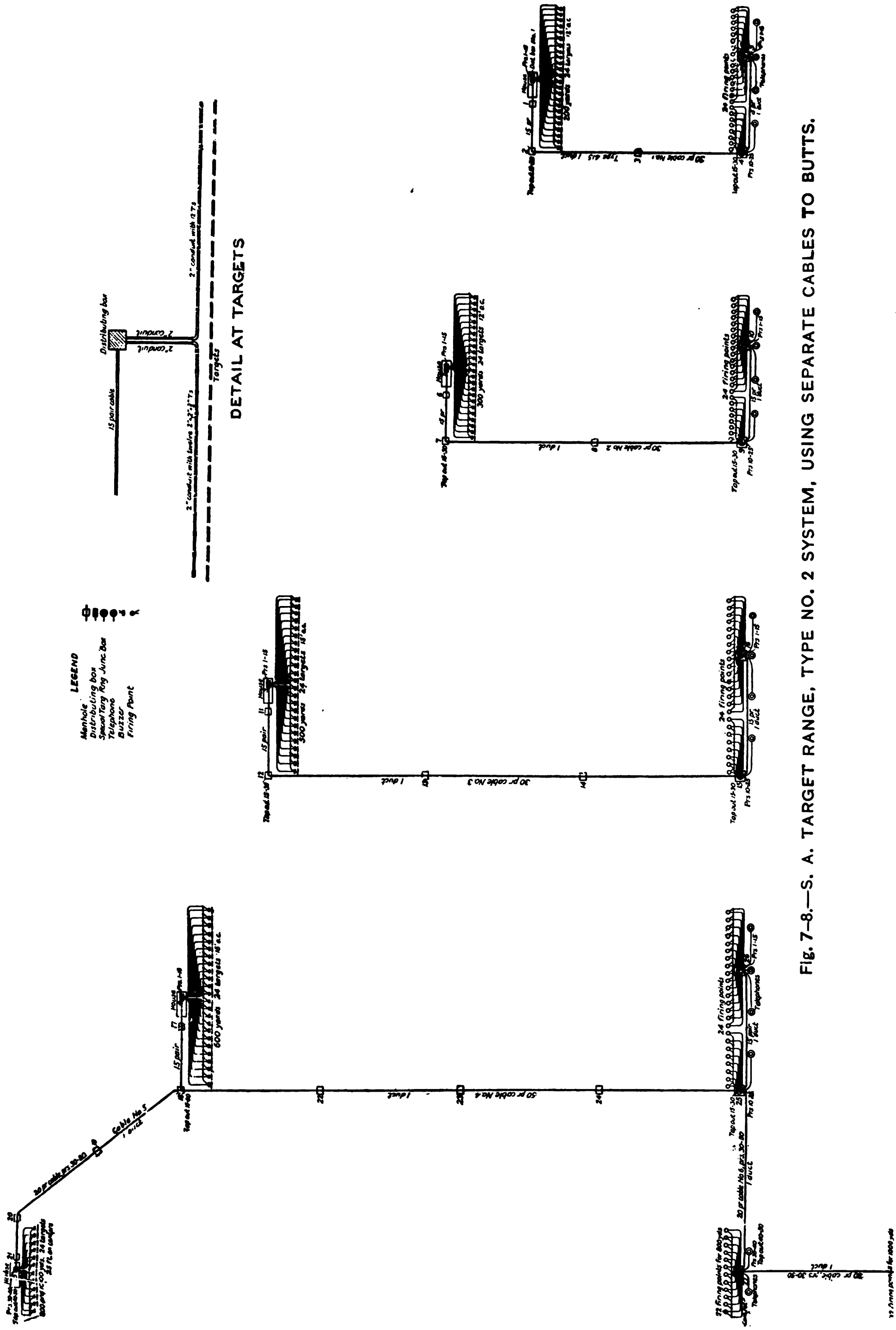


Fig. 7–8.—S. A. TARGET RANGE, TYPE NO. 2 SYSTEM, USING SEPARATE CABLES TO BUTTS.

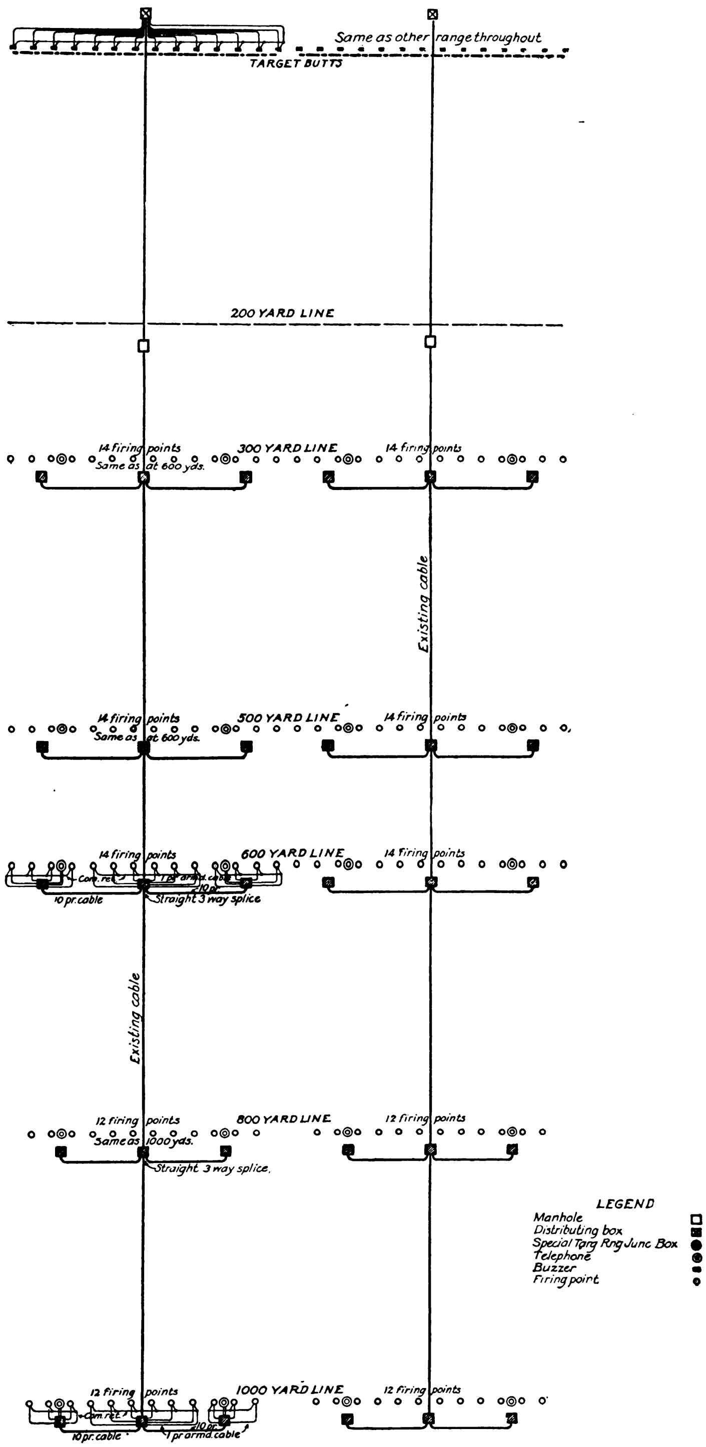


Fig. 7-9.—S. A. TARGET RANGE, TYPE NO. 3 SYSTEM.

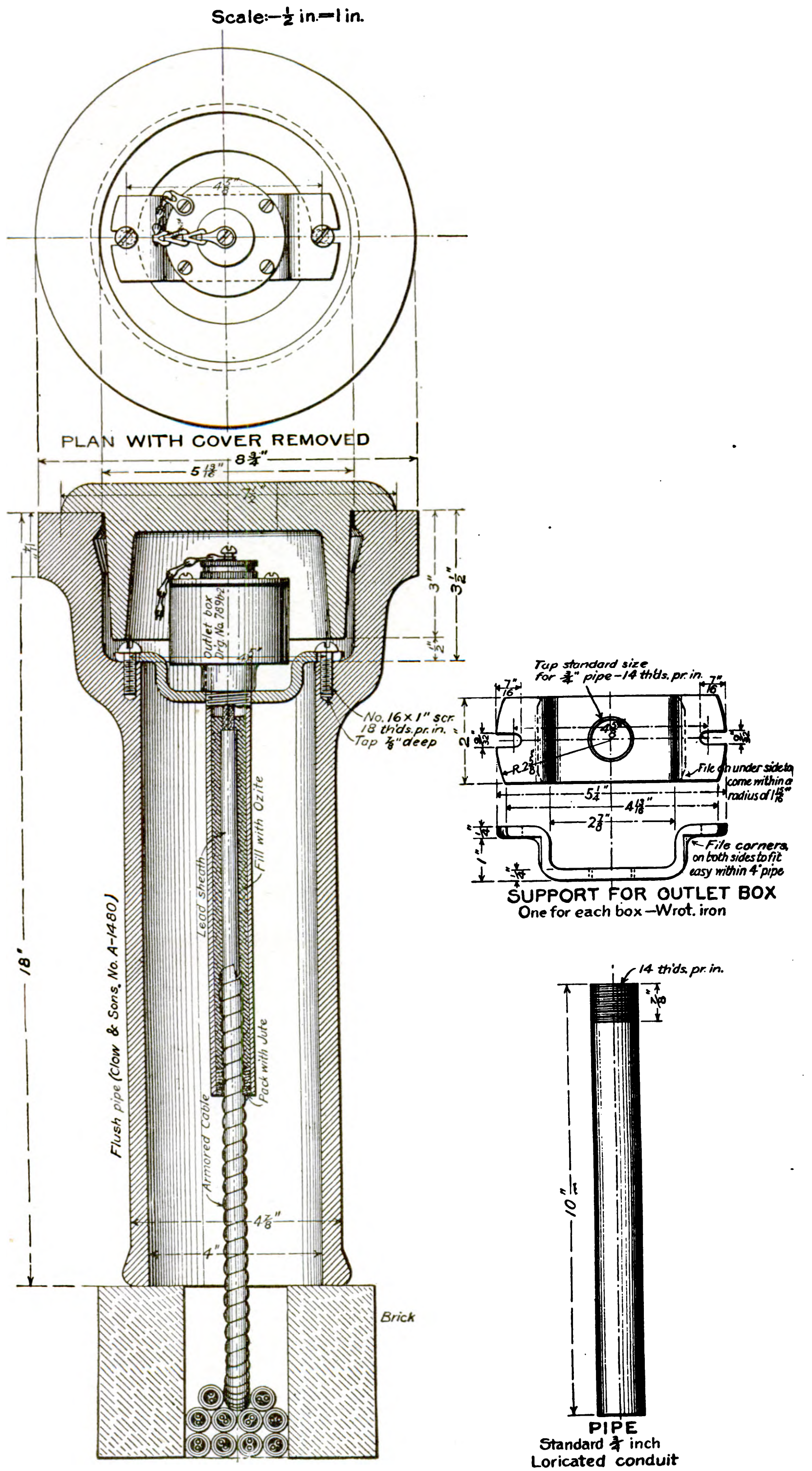


Fig. 7–10.—S. A. TARGET RANGE, TYPES 2 AND 3 SYSTEMS, OUTLET BOX, INSTALLATION OF.

compound. Installation of 1915 model outlet box is similar, the box being provided with supporting lugs. It will be noted that the sewer flush pipes are equipped with a substantial removable cover.

Military drills by various arms of the service are sometimes held on small-arms ranges and with outlets installed as shown, little or no inconvenience is occasioned the troops. When the soil is soft and the wheel of an artillery field-piece comes in contact with one of these flush pipes it may be deflected from the vertical position, but no injury results as sewer flush pipe, outlet box, and sealing chamber are moved as a unit, the type 251 cable being flexible. The pipes are easily returned to correct position after such an occurrence.

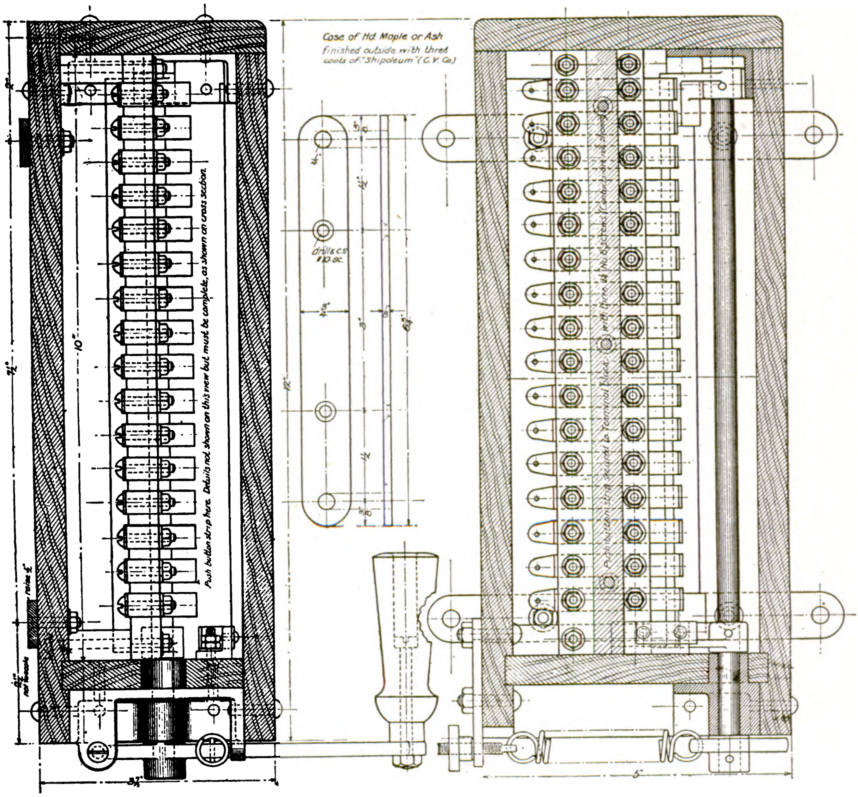


Fig. 7–11.—S. A. TARGET RANGE, TYPES 2 AND 3 SYSTEMS, MASTER SWITCH.

Figure 7–11 shows the construction of a master switch for a range having 16 targets. These switches have been furnished for ranges having 24 targets, and while they can be made for a greater capacity on the very large ranges, it is believed advisable to install two switches, arranged to be operated simultaneously, if desired.

Figure 7–12 shows construction of manhole usually used in connection with buzzer annunciator system. One of these manholes is constructed at each firing line on line of each main cable with the type 3 system. With the type 2 system location and number is dependent upon local conditions.

In these manholes are installed the target range junction box from which distribution (by means of type 251 cable) of circuits to outlet boxes is made. It will be noted that cover of manhole is 6 inches below surface of earth so that it is unnoticed when drills on range are held. If Artillery drills are held on range it is advisable to provide extra support for boiler-plate cover. A

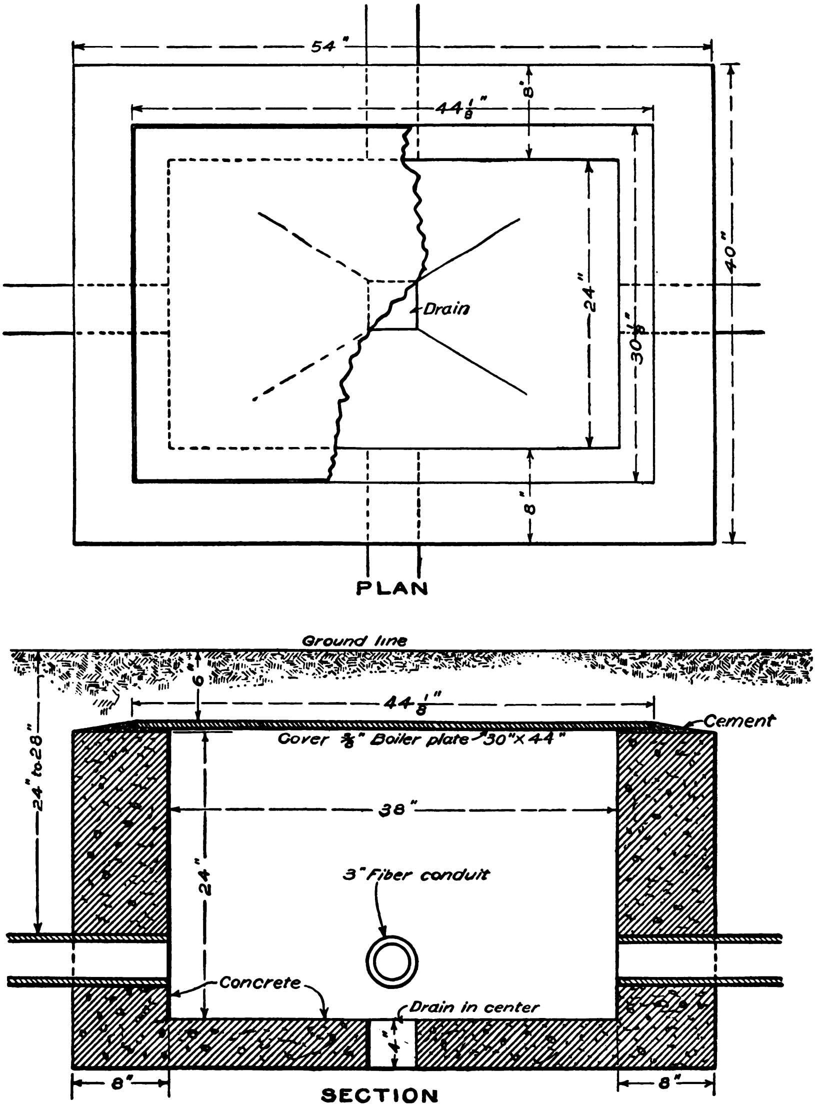


Fig. 7–12.—S. A. TARGET RANGE, TYPES 2 AND 3 SYSTEMS, MANHOLE.

small 3-inch eyebeam across center of manhole, supported by manhole and removable at will, is an excellent method of providing this extra support.

Figure 7–13 shows the construction of the target range junction box, usually installed in manholes just described. Suitable openings are provided in bottom of box for entrance of a tap from main cable and a number of type 251 cables. Tap from main cable enters through circular opening and type 251 cable through elongated openings on either side of circular opening. The box will accommodate three Signal Corps standard porcelain terminal strips to which conductors of cables are connected and where proper cross connection can be made.

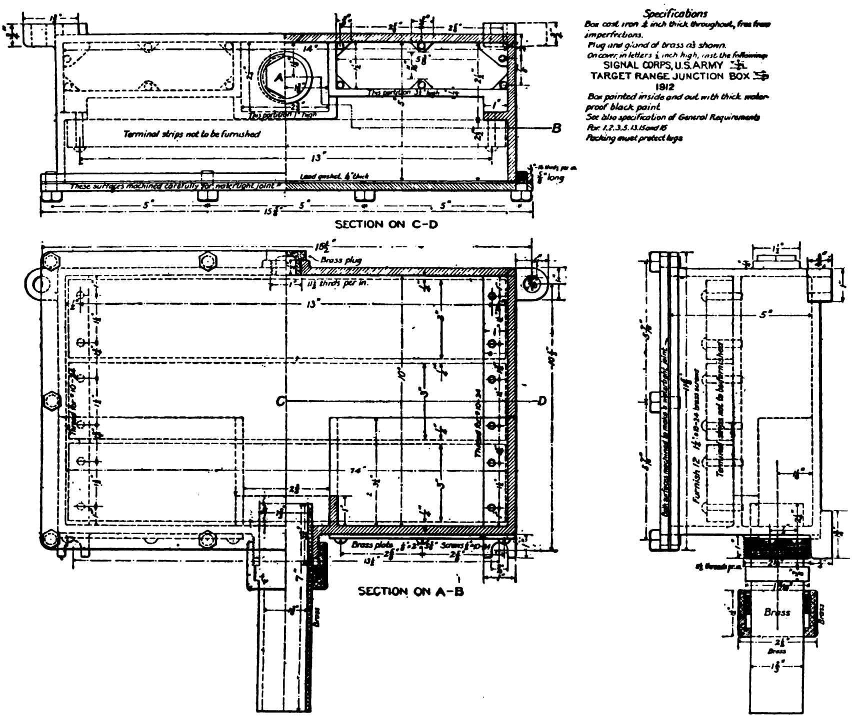


Fig. 7–13.—S. A. TARGET RANGE, TYPES 2 AND 3 SYSTEMS, TARGET RANGE JUNCTION BOX.

Figure 7–14 shows the construction and arrangement of equipment of the distributing box for target ranges. This box is installed at the butts and contains the 20 cells of dry battery which furnishes current for operating the buzzers and annunciator for each range. This box also contains three suitable commercial terminal strips to which are connected conductors of cable to firing points and rubber-covered wires to buzzers, strap keys, annunciator, master switch, and telephone at butts. Appropriate cross connections of the various lines are made at these terminal strips with No. 16 rubber-covered wire.

Figure 7–15 shows the manner of installing the buzzer and strap key. The two pieces of apparatus are mounted on a hard maple backboard provided with brass lugs through which pass the screws which fasten it to parapet wall. A sheet-metal cover is provided for protecting the buzzer and strap key from the elements. This cover is held in position by four brass screws in side edges of maple backboard. These screws are so inserted that the heads are distant from backboard the thickness of metal cover. Slots are cut in metal cover for engaging the screws, and the cover can be placed in position or removed without removing the screws. The strap key can be operated without removing metal cover, as there is an opening with slide cover for this purpose.

While a number of strap keys and buzzers have been installed in this manner, it is intended that in future a small metal box in the form of a condulet into which the three-fourth inch conduit will be threaded will be supplied for the purpose.

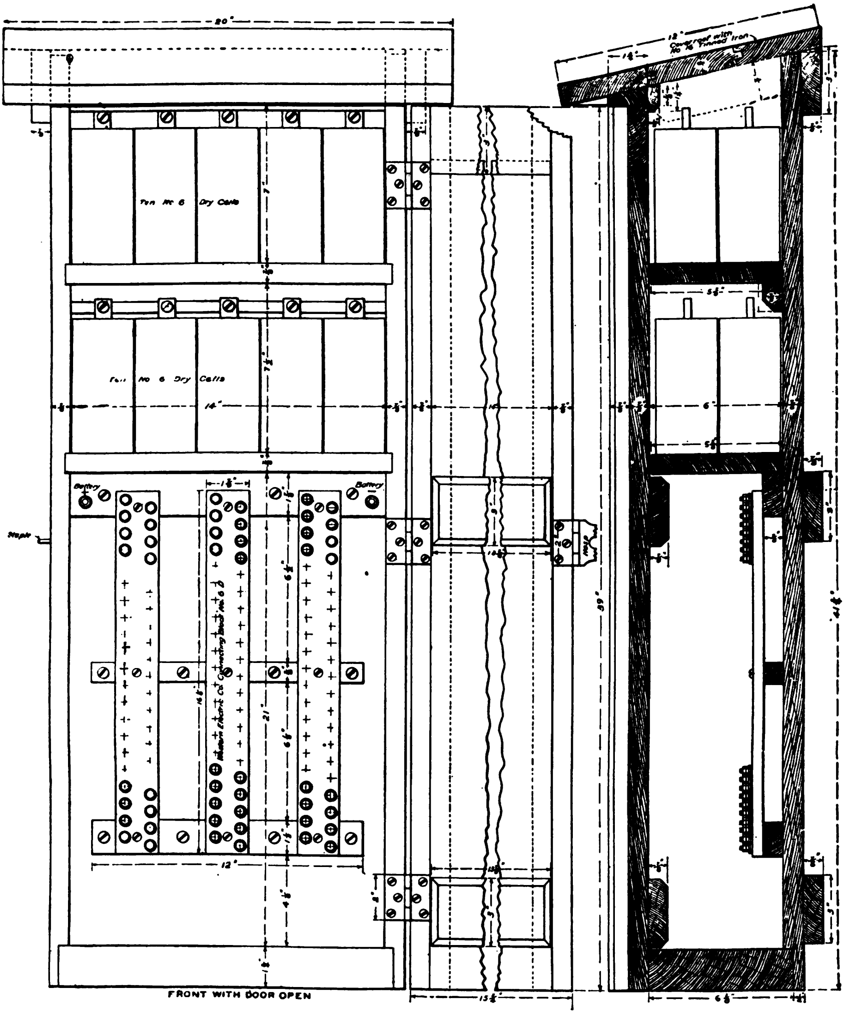
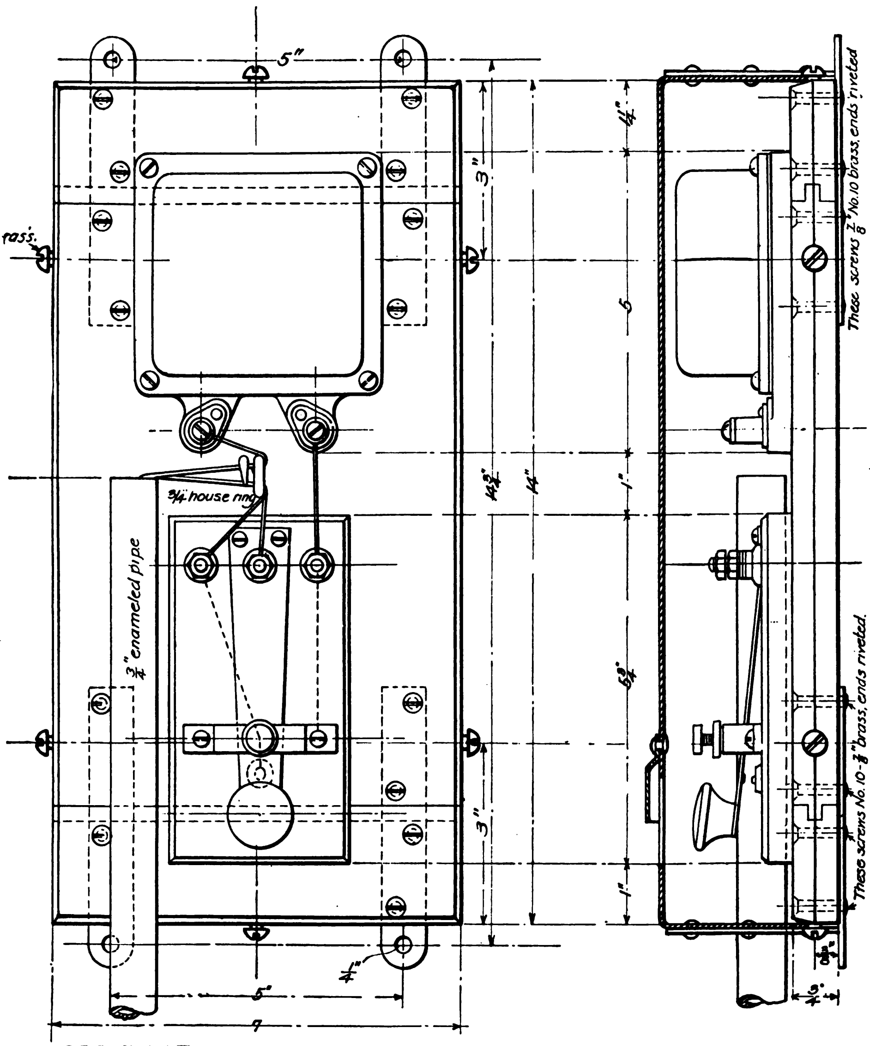


Fig. 7-14.—S. A. TARGET RANGE, TYPES 2 AND 3 SYSTEMS, DISTRIBUTING BOX.

The standard method of wiring between the distributing box and the buzzers and strap keys is as follows:

Loricated conduit from distributing box to flank buzzers and strap keys is securely fastened to parapet wall, the means of fastening being dependent on material of which parapet wall is made. This line of conduit is below the horizontal plane of position of the buzzers and strap keys. At each buzzer and strap key this conduit line is provided with a pipe tee, the tap opening being for three-fourth inch conduit. A piece of three-fourth inch conduit ending on a horizontal level midway between buzzer and strap key is threaded into tap opening of pipe tee and the upper end of this conduit should be sealed with Chatterton compound after wire mentioned later has been pulled in the conduit.



FRONT WITH COVER REMOVED

Fig. 7–15.—S. A. TARGET RANGE, TYPES 2 AND 3 SYSTEMS, INSTALLATION OF STRAP KEY AND BUZZER.

Rubber covered and braided wire, conductor 51 mils, is used for the connections between distributing box and buzzer and strap keys. This wire should be pulled in the conduit simultaneously with the placing of conduit, as the wire can not be pulled around the sharp corners of the pipe tees.

Figure 7–16 shows a diagram of through circuits. Referring to this figure it will be seen that one wire is common to center post of all strap keys. This wire should not be tapped but should be looped to center binding post of each strap key, the loop extending from pipe tee to strap key.

The size of conduit for the main run is dependent upon the number of targets on the range and in some instances it may be advisable to use two or more sizes, reducing the size as distant outlets are reached. If it is impracticable to locate the distributing box near longitudinal center of parapet wall on a range having 30 or more targets, cable should be installed between distributing box

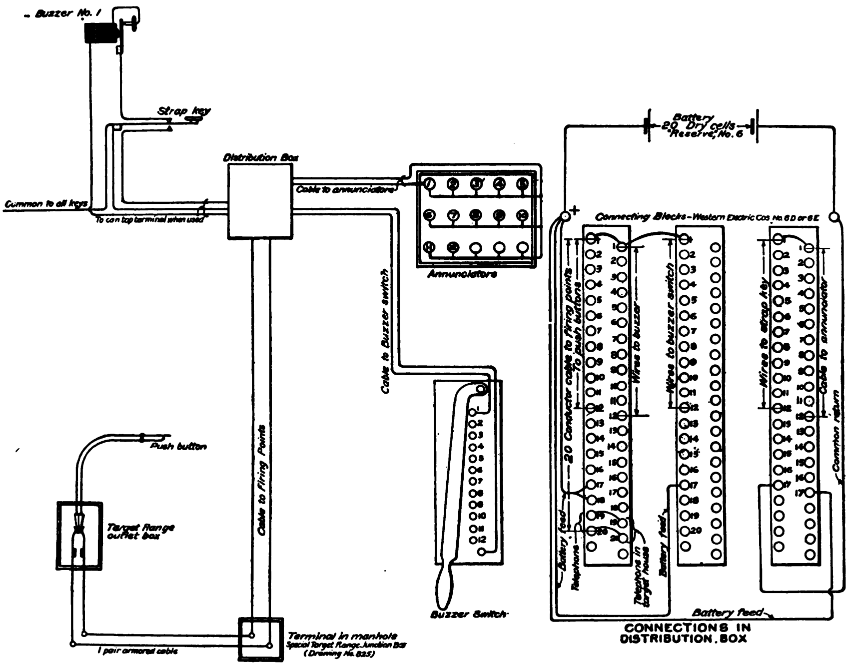


Fig. 7–16.—S. A. TARGET RANGE, TYPES 2 AND 3 SYSTEMS, THROUGH CIRCUITS.

and one or more can terminals, appropriately located, and conduit lines extended from can terminals to buzzers and strap keys. Figure 7–17 illustrates such an arrangement. It is also applicable under some conditions where the number of targets exceeds 50, regardless of whether or not distributing box be located near longitudinal center of parapet wall.

When approved in each individual case by the Chief Signal Officer of the Army, the small-arms range may be connected telephonically with nearest post telephone system.

The wiring for annunciator and master switch is dependent upon conditions. In some instances the master switch is mounted on the side of the distributing box, in the event of which it is only necessary to make a neat form of sufficient number of rubber-covered wires extending the wires from terminal strip through side of box to master switch. If the master switch or annunciator are placed distant from distributing box, the connecting wires should be in iron conduit of suitable size.

As funds become available for the construction of systems corresponding to types 2 and 3 special plans will be drawn to meet the varying conditions of the ranges that may be selected.

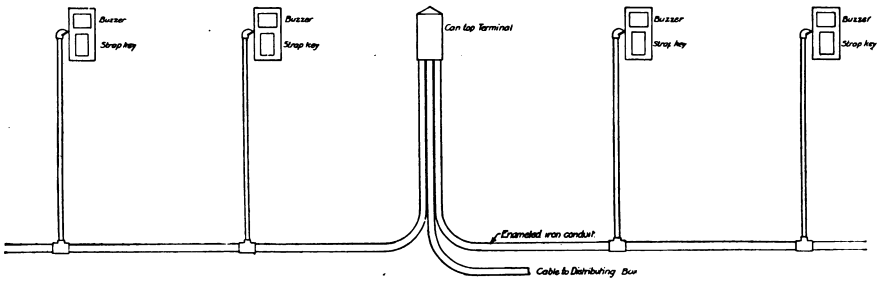


Fig. 7-17.—S. A. TARGET RANGE, TYPES 2 AND 3 SYSTEMS, USE OF CAN TERMINAL.

For some of the large rifle ranges the Signal Corps has supplied a portable, direct-reading anemometer. The use of these instruments is confined to preliminary drills for instruction in wind reading. They will not be allowed on the range during the regular practice season or during competitions. (M. S. O., 1201729.)

RECORDS.

As previously stated in this manual, in no branch of the industrial field are records of such great importance as those pertaining to electrical installations.

The Signal Corps requires that upon completion of a small-arms target range signaling system a complete and accurate record be prepared by the person in responsible charge of installation of the system.

This record consists of standard Signal Corps forms appropriately accomplished and drawings illustrating connections, cross connections, routing of cables, and location of manholes and location of apparatus. All prints of tracings and page 8 of Signal Corps Form No. 211 are submitted in triplicate if range is for the United States Army and in quadruplicate if for the militia. One complete copy of the record is furnished for office of each of the following officials:

Chief Signal Officer of the Army.

Department Signal Officer of the department in which the range is located.

Commanding Officer of post to which the range is attached.

In addition at least one copy of drawing shown under subheading "*a*," appearing later in this chapter, shall be transmitted to the local post quartermaster that he may be familiar with location of Signal Corps cable and conduit system.

If the range be for an organization of the militia, the latter copy and an additional one should be forwarded to the Chief Signal Officer of the Army for transmittal to the Chief, Division of Militia Affairs, General Staff, one copy being for the files of his office and one for him to transmit to Adjutant General of the State militia, who will decide its custody.

The drawings should be made by means of waterproof ink on tracing cloth. When installation of a system is made by the Signal Corps, United States Army, and it is impracticable to make these drawings where installation of system is made, the data should be forwarded by person in responsible charge of the work to the Department Signal Officer of the department in which the range is located. The Department Signal Officer will have the tracings made, if facilities are available in his office, using the data furnished as a guide. If impracticable to make the drawings in the office of the Department Signal Officer, the data should be forwarded to the Chief Signal Officer of the Army with request that the drawings be made.

The upkeep of these records is important and all authorized changes should be recorded. It is the duty of signal officers to see that all modifications of the original system are reported in order that the tracings may be revised and the various offices furnished a print of the revised tracing. If the system installed be for the United States Army, and there are facilities for changing the drawings (tracings) and for making prints in the office of the Department Signal Officer, the tracings will be filed in that office, otherwise they will be filed in the office of the Chief Signal Officer of the Army. If the system installed be for the militia, the custody of the tracings should be decided by the Chief, Division of Militia Affiairs, in each individual case.

Component parts of the record required are as follows:

(*a*) One or more drawings, map, to scale, showing routing, type, Signal Corps number of reel from which taken, and splices of all cables and routing of aerial lines if there be any, location of manholes, and all apparatus installed. If conduit for cables is used, the kind and size should be indicated. The distance between center of manholes and each of the two outlet boxes on either side should be accurately shown as the surface indication of these underground manholes is ofttimes obliterated.

(*b*) Drawing, diagram, not necessarily to scale, showing all connections and cross connections. This should include all connections and cross connections in distributing boxes, all connections and cross connections in junction boxes, and an outline of the circuit. A statement in the form of a note relative to average insulation measurement of conductors of cable should appear on this drawing. If cables contain any defective conductors, they should be indicated as such. This drawing may be combined with drawing described under (*a*) if crowding does not result.

SIGNAL CORPS FORMS.

(*c*) Signal Corps Form No. 211 (report of inspection of Signal Corps equipment). The lower half of page 8 of this form pertains to rifle-range equipment and should be accomplished for each copy of the record by person in responsible charge of an installation.

(*d*) Signal Corps Form No. 282 (cost data of target-range system). This form should be accomplished in duplicate (regardless of whether the system be for United States Army or militia) by person in responsible charge of installation of the system. One copy is for the files of the Chief Signal Officer of the Army and one for the files of the Department Signal Officer of department in which range is located.

On large ranges, when sufficient funds are available, the longitudinal cables should either be armored or placed in conduit, the former being preferable. A number of systems using plain lead-covered cable trenched have been put out of commission by gophers gnawing through lead sheath. The same has happened with plain lead-covered cable in conduit where conduits were not sealed at manholes. Where plain lead-covered cable is used, every precaution should be employed to prevent rodents entering the conduit system, for while this trouble apparently is not experienced in cities and at most Army posts it has actually occurred in the Philippine Islands and at some places in continental United States. The lateral cables from target-range junction boxes to push-button outlets should invariably be type 251 (one pair lead-covered and armored), and trenched.

Chapter 8.

TECHNICAL EQUIPMENT ISSUED BY THE SIGNAL CORPS.

This chapter is devoted to an enumeration of latest technical equipment issued, with brief description of various items. It is prepared with a view of assisting in the preparation of requisitions.

For description of items representing apparatus for fire-control systems at seacoast defenses the reader is referred to Signal Corps Manual No. 8, revised edition.

Information relative to the cost of material listed may be obtained from the current Signal Corps price list issued annually at the beginning of the fiscal year.

The technical equipment issued includes the following:

Alcohol:
- Denatured.
- Wood.

Anchor, expansion, bolt, shield $\frac{5}{8}$ by 2 inches, screw $\frac{3}{8}$ by 3 inches (without lag screws).

Anchors, expansion, screw:
- 1-inch, without screws, for Nos. 9, 10, and 11 wood screws.
- $1\frac{5}{8}$-inch, without screws, for Nos. 9, 10, and 11 wood screws.
- 2-inch, without screws, for Nos. 9, 10, and 11 wood screws.

Anemometers, portable, with tripod and cups.

Anemometer stop watch.

Annunciators, target range:
- 10-signal.
- 20-signal.
- 25-signal.

Ardois lights, sets, complete:
- Globes, telephoto, for Ardois. Specify whether red or white and name of manufacturer of set.

Arresters, Mason, fused:
- Coils, choke, with carbon blocks and mica insulators, in pairs.

Asbestos, sheet (thickness to suit requirements).

Axes:
- Helves for.

Axes, hand:
- Handles for.

Bags, tool, service. (See p. 68, this chapter.)

Bars, digging and tamping.

Barometers.:
- Aneroid.
- Mercurial.
  - Box, wooden, for.

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Batteries:

- Dry—
  - Miniature.
  - No. 4–0, Reserve type.
  - No. 6, Reserve type.
  - Tungsten, type A (2-cell units).
- Edison primary battery, type V—
  - Complete.
  - Renewals for, complete.
  - Jars for.
  - Covers for.
- Fuller—
  - Complete.
  - Jars for.
  - Porous cups for.
  - Covers for.
  - Carbons for.
  - Zincs for.
  - Chromac for.
  - Mercury for.
  - Gaskets, rubber, for cover of.
- Gravity, 5 by 7 inches, main line—
  - Bluestone.
  - Coppers for.
  - Jars for.
  - Zincs for.
- Storage—
  - Type A, 15-cell (10-ampere rate).
  - Type B, 15-cell (15-ampere rate).
  - Type ET, coupled (4½-ampere rate).
  - 6-volt, 80 ampere hours (for audion detectors).
    - Maintenance parts—
      - Electrolyte, 1.200 S. G. (120-lb. carboy).
      - Electrolyte, 1.400 S. G. (120-lb. carboy).
        - Carboys for (not included in the above).
      - Elements, negative (for 10-ampere rate).
      - Elements, positive (for 10-ampere rate).
      - Hydrometer.
      - Insulator, glass, petticoat, for tray.
      - Jars, glass.
      - Jars, rubber, with covers.
      - Plates, positive or negative.
      - Separators.
      - Syringe, hard-rubber.
      - Thermometer, floating type.
      - Trays, sand (for 10-ampere rate).

      NOTE.—In requesting any parts for storage batteries, the manufacturer, type, and any other relative data must be supplied, in order that the proper parts may be supplied.

Beeswax.

Bellows, motor generator.

Bells, extension, loud ringing, with condenser. (See p. 22, this chapter.)

Belts, lineman's tool, with rings and safety straps.
Bicycles, chain.
Blanks, telegraph:
- Message received.
- Message sent.

Blotters, small.
Blocks:
- Connecting, W. E.—
  - 6A (7-pair).
  - 7A (1-pair).
  - 6B (11-pair).
  - 6C (16-pair).
  - 6D (21-pair).
- Terminal, telephone.

Boards, letter clip.
Bolts:
- Expansion (see Anchors).
- Carriage (for securing brace to cross-arm), $\frac{3}{8}$ by 4 inches.
- Lag (for securing brace to pole). (See Screws, lag.)
- Cross-arm (for securing cross-arm to pole) (give length desired)—
  - $\frac{5}{8}$ by 10 inches.
  - $\frac{5}{8}$ by 12 inches.
  - $\frac{5}{8}$ by 14 inches.
  - $\frac{5}{8}$ by 16 inches.
  - $\frac{5}{8}$ by 18 inches.
  - $\frac{5}{8}$ by 20 inches.
- Machine (give length and size)—
  - $\frac{3}{8}$ by 6 inches.
  - $\frac{3}{8}$ by 8 inches.
  - $\frac{3}{8}$ by 10 inches.
  - $\frac{3}{8}$ by 12 inches.
- Stove (give length and size)—
  - $\frac{1}{8}$ by 2 inches.
  - $\frac{1}{4}$ by 4 inches.
  - $\frac{1}{2}$ by 6 inches.
  - $\frac{1}{2}$ by 8 inches.
- Toggle (give length and size)—
  - $\frac{1}{4}$ by 3 inches.
  - $\frac{1}{2}$ by 6 inches.

Books, field message (Form 217A).
Boxes (also see p. 20, this chapter):
- Connecting.
- Distributing.
- Junction, iron.
- Outlet, circular type—
  - Bases, porcelain, for.
  - Gaskets, for.
  - Plugs for, with 8-foot cord, with lignum-vitæ tips.
  - Supports for.
  - Without plugs.
- Outlet, marine type, complete with plugs.
- Cable pole, Sterling, complete, with tubular fuses and carbon arresters.

Boxes—Continued.
- Cut-out, 2-switch.
- Cut-out, 3-switch.
- Junction, iron, 3-way.
- Outlet, searchlight.
- Switch, base line.
- Terminal, fire-control type (see p. 20, this chapter)—
  - 2-strip, metal, 1915 model.
  - 4-strip, metal, 1915 model.
  - 8-strip, metal, 1915 model.
- Transfer, switch—
  - 2-switch type.
  - 4-switch type.
- Time-interval bell.
- Terminal, submarine—
  - Type No. 1.
  - Type No. 2.
  - Type No. 3.
  - Type No. 4.

Braces, cross-arm (1¼ inches wide, ¼ inch thick; give length desired):
- 20-inch.
- 22-inch.
- 24-inch.
- 26-inch.
- 28-inch.

Brackets:
- Iron, for lance poles.
- Oak, for glass insulators.

Brushes, paint, all sizes (give size and whether round or flat).

Buckets, water, canvas.

Buttons:
- Push—
  - Leather cover for.

Buzzers, Faraday type, 150-ohm:
- Covers for.

Buzzer, service, model 1914 (the 1914 service buzzer when furnished complete consists of 1 buzzer with dry batteries, tools, connecting cord, plug, type A connector (Williams's test clamp), transmitter and receiver, and type D ground rod).

Buzzer, service, model 1914—maintenance parts:
- Batteries, dry, tungsten, type A.
- Block, connecting, for condensers, complete, assembled.
- Buttons—
  - Hard rubber, for key.
  - Transmitter switch.
- Caps—
  - Receiver.
  - Transmitter.
- Coil, complete, with back irons and bracket, without contact screw, mountings, and vibrator.
- Condensers.
- Connector, type A (see p. 89, this chapter).

Buzzer, service, model 1914—Continued.
- Cords—
  - Main, with terminals.
  - Transmitter and receiver (also for receiver of Field Artillery telephone).
- Cups, fiber, for plugs (also for plugs of Field Artillery telephone).
- Doors, battery, complete, with hinges, contacts, and covers.
- Headbands, receiver (also for Field Artillery telephone).
- Key, lever, complete.
  - Supports and screws.
  - Screws, fulcrum.
  - Screws, platinum contact, for key handle.
  - Screws, platinum contact, under key, auxiliary.
  - Screws, platinum contact, under key, main.
- Latches, washers, and screws.
- Nuts, hexagon, for base wiring, 4–36.
- Plugs, complete.
  - Jacks, plug seat.
  - Springs, for jack.
  - Rods, steel, for plug.
- Posts, binding.
- Receiver, with headband and cords.
  - Diaphragm for.
  - Cap for.
- Screws, adjusting, with platinum contact, for vibrator.
  - Adjusting.
  - Clamp, filister head, $\frac{3}{8}$-inch, 5–40, for vibrator.
- Spring and support.
  - Battery contact, right.
  - Battery contact, left.
- Spring and piece for condenser.
- Spring, for key.
- Straps, carrying, complete.
- Switches, lever, complete, for receiver.
- Transmitter, with cords, complete.
  - Diaphragm, for transmitter.
- Vibrator, complete (11 pieces).
- Washers, micanite (or mica) for back of transmitter case.
- Wrenches, socket, complete, with screw driver.

Cabinets:
- File, storekeeper's.
- Supply.
- Terminal.

Cables, all types (for complete list see p. 25, this chapter; for description and detailed characteristics see chapter 4).

Cables, submarine, gear and supplies (see p. 30, this chapter).

Candles, for folding candle lantern.

Cans:
- Gasoline, 1-gallon size.
- Oil, steel, pint size.
- Oil, 10-inch, bent spout, copper.

Cards, code, semaphore.

Carriers, wire, for buzzer wire (see p. 87, this chapter).
    Covers for.
Cartridges (for Very pistols).
    Very—
        Green.
        White.
        Red.
        Smoke (for day use).
Carts, signal. (See p. 23, this chapter.)
Carts, wire. (See p. 33, this chapter.)
Case:
    Battery (for holding 6 type A tungsten dry batteries).
    Map.
Case, electrical instrument, complete. (See p. 54, this chapter.)
Cases, reagent, for testing storage batteries.
Cells, dry. (See chapter 1.)
Cement, rubber, ½-pint cans.
Charges, carbide, for field acetylene lantern.
Chests, tool:
    Aeroplane. (See p. 58, this chapter.)
    Construction. (See p. 62, this chapter.)
    Cable splicer's. (See p. 64, this chapter.)
    Electrical engineer's. (See p. 60, this chapter.)
    Mechanic's No. 1. (See p. 55, this chapter.)
    Mechanic's No. 2. (See p. 55, this chapter.)
    Pipe fitter's. (See p. 65, this chapter.)
    Post. (See p. 66, this chapter.)
Chisels, cold, 6-inch.
Circuit breaker (circuit breakers are furnished as a part of the various power switchboards, and in requesting repair parts state whether single or double pole, capacity, overload or underload, or reverse current, manufacturer's name, type and code number, and, if practicable, catalogue number):
    Double pole, overload and reversite breaker, calibrated 35–70 amperes.
    Type E. L., single pole, plain overload, rated 20 amperes.
Clamp, splicing.
Clamps:
    Cable, large.
    Cable, small.
    Ground.
    Guy, 2-bolt.
    Guy, 3-bolt.
Cleats:
    Porcelain, 1-wire (for inside wiring for telephones).
    Porcelain, 2-wire.
    Porcelain, 3-wire.
    Wood, cross-arm.
Climbers, with straps, pairs.
Clips:
    Testing.
    Crosby, ⅜-inch.
Clocks, alarm.

Cloth:
- Crocus, sheets.
- Emery, No. 00 to No. 1½, sheets—
  - No. ½.
  - No. 1½.

Coal oil.

Coil, repeating.

Coil, retardation.

Compound, Chatterton's. (See p. 45, this chapter.)

Compass, pocket.

Condensers (the type of condenser, manufacturer, and type of equipment for which it is required should be stated):
- Western Electric No. 21F, for common battery telephones.
- 2-microfarad.
- 8-microfarad.

Conduit (also see p. 43, this chapter):
- Bituminized fiber—
  - 2-inch.
  - 2½-inch.
  - 3-inch.
  - Compound for joints.
- Flexible, Greenfield—
  - ½-inch.
  - ¾-inch.
  - 1-inch.
- Loricated—
  - ¾-inch.
  - 1-inch.
  - 1½-inch.
  - 2-inch.
  - 2½-inch.
  - Elbows for—
    - 1-inch.
    - 1½-inch.
    - 2-inch.
    - 2½-inch.

Condulets, pipe, F. P., ¾-inch.

Connectors:
- Type A, main cord of service buzzer (see p. 89, this chapter)—
  - Studs for, 19-point.
  - Terminal, for cord.

Cord:
- Antenna, 42-strand (for radio masts).
- Sash—
  - 3/16-inch, No. 6 ((66 feet to pound).
  - ⅜-inch, No. 12 (20 feet to pound).
  - ⅜-inch, No. 5 (20 feet to pound).
- Buzzer, main (for service buzzers).
- Lamp—
  - No. 14, reenforced.
  - No. 16, reenforced.
  - No. 18, reenforced.

(For various kinds of electrical apparatus cords see p. 35, this chapter.)

Cotton, strips, rolls, for cable splicing, 10-yard rolls.
Covers:
  Canvas, telephone motor generator.
  Handhole.
  Iron, manhole, 44 by 30 by ⅜ inch (140 pounds each).
  For wire carriers.
Crank, reel cart.
Cross arms:
  For iron poles, complete with bolts.
  Wooden, 2 to 10 pin, bored for 1½-inch pins (state number of pins required)—
    2-pin.
    6-pin.
    10-pin.
    Braces, galvanized iron, 20 to 28 inch lengths, for (state length).
    Braces, galvanized iron, 28-inch, for.
Cut-out, porcelain, wall (main or branch, in sizes to suit requirements; give carrying capacity of fuse).
Disks, cipher.
Envelopes:
  Message.
  Penalty.
Equipment, lighting, for F. C. switchboard rooms.
Erasers, rubber.
Fault-finder, Leeds & Northrup.
Files, property return.
Flashlights, electric, complete.
  Batteries for (tungsten, type A).
  Bulbs (lamps) for (Mazda "A").
Frame, name plate, No. 2, with celluloid cover.
Fuses (also see p. 42, this chapter):
  For Mason arrester, 1 ampere (type 9).
  Cook, type A7, 5 amperes.
  Cook, type A12, 3 amperes.
  Type 1, 5 amperes.
  Type 1, 10 amperes.
  Type 2, 5 amperes.
  Type 2, 10 amperes.
  Type 3, 5 amperes.
  Type 3, 10 amperes.
  Type 3, 15 amperes.
  Type 3, 20 amperes.
  Type 3, 25 amperes.
  Type 3, 30 amperes.
  Type 4, 31 amperes.
  Type 9, 1 ampere (for Mason arrester).
  For Sterling No. 247E protectors, 5 amperes.
  W. E., type 35B, 5 amperes.
  W. E., type 7A, 3 amperes.
Gasoline.

Glasses, field.
  Type A, with case.
    Case for.
  Type B, with case.
    Case for.
  Type C, with case.
    Case for.
  Type D, with case.
    Case for.
  Type EE.
    Case for.
  Description of each of these field glasses will be found on pages 40 and 41, this chapter.
Grips, Buffalo, No. 1, with pulleys.
Hammers, carpenter's.
Hand-set switch, 1 key.
Hand-set switch, 2 keys.
Handles, pay-out.
Hangers, cable, galvanized iron, 2-inch, with 3 hooks.
Hatchets.
  Handles for.
Heliographs, complete, with two tripods.
  Maintenance parts—
    Cases—
      Leather, carrying.
      Wood, for mirror.
    Frame and mirror, complete.
    Heads, tripods, for mirror bar.
    Keys with bars for screen.
    Mirror, field.
    Points, steel, for tripods.
    Rods, sighting.
    Screens, complete.
    Screw drivers.
    Screws—
      Adjusting, with clamps, for mirror frame.
      Center, for tripods.
      Tangent, for mirror bars.
    Shutter, complete.
    Springs, mirror bar.
    Tripods, each (2 furnished with heliograph).
Hoods, metal, for buzzer and strap key.
Hooks, message.
Houseline.
Ink (writing fluid), pints.
Insulatine.
Insulating compounds. (See p. 44, this chapter.)
Insulating materials. (See p. 44, this chapter.)
Insulators:
  Clamp.
  Pigtail.

Insulators—Continued.
  Glass—
    Double groove.
    Double petticoat.
    Pony.
    Transposition.
  Pony, porcelain, double groove.
  Knobs, porcelain (give size)—
    No. 4.
    No. 5.
    No. 14.
Iron, strap.
Jack, wagon.
Jacks, cable reel (state lifting capacity desired):
  5-ton.
  Axles for (give diameter and length).
  Axles, 2 inches by 6 feet, for.
Keys:
  Strap, with slate base. (See p. 43, this chapter.)
  Telegraph, leg or legless, open or closed circuit.
Kits:
  Flag—
    Combination, standard (consisting of 1 case, canvas; 1 staff, 3-joint; 1 flag, red, white square; 1 flag, white, red square; 2 staffs, semaphore; 2 flags, semaphore, standard).
    Combination, Artillery (same as "combination, standard," except that 2 flags, semaphore, Artillery, are substituted for the 2 flags, semaphore, standard).
    Combination, Infantry (same as "combination, standard," except that 1 Infantry flag is substituted for the 2 red and white flags).
      Maintenance parts—
        Case, canvas.
        Staff, 3-joint complete—
          Lower joint.
          Middle joint.
          Upper joint.
        Staff, semaphore.
        Flags—
          Red, white square.
          White, red square.
          Semaphore (combination or Artillery).
          Infantry (regular organization).
          Infantry (militia).
    Flag, 4-foot, complete.
      Maintenance parts—
        Case, canvas.
        Staff, 3-joint, complete.
          Lower joint.
          Middle joint.
          Upper joint.
        Flags—
          Red, white square.
          White, red square.

Kits—Continued.
- Inspector's pocket, complete (for full description see p. 69, this chapter).
  - Maintenance parts—
    - Cases, leather.
    - Files, 3-inch.
    - Knives, electrician's.
    - Pliers, 5-inch, side-cutting, nickeled.
    - Rules, 2-foot.
    - Scissors, electrician's.
    - Screw drivers.
    - Tweezers.

Knives:
- Brush cutting.
- Electrician's.

Lacquer, transparent, ½-pint tins.

Lamps, battery examining, 20-volt, Edison base.

Lanterns:
- Acetylene, field, complete, without tripods (tripods furnished with heliographs are used).
  - Maintenance parts—
    - Base, complete, with key.
    - Burners for.
    - Bushings, water-tube.
    - Caps—
      - For inlet tube, with needle point.
      - For safety outlet, without holes.
      - Generator, with gooseneck.
    - Cases.
    - Charges, carbide.
    - Cleaners.
    - Cocks, gas.
    - Covers, complete, with front glass.
    - Diaphragms for carbon holder.
    - Gasket, rubber, for top and bottom, cartridge opening.
    - Generator, complete.
    - Glass, front, complete.
    - Hose, rubber.
    - Lead, white, tubes.
    - Lens (see Glass).
    - Mirrors, reflecting.
    - Needles, for cleaning burners.
    - Pliers, gas, 6-inch.
    - Screw driver.
    - Springs—
      - Key, new style.
      - Key, old style.
      - For holding carbide cartridge.
    - Stopper, rubber.
    - Straps, carrying.
    - Tips, lava.
    - Tripods, each (not furnished with acetylene lantern; use one of two with heliograph.
    - Tubes, outlet, with screw cap and gas cock.

Lanterns—Continued.
  Candle, folding.
    Candles for.
  Coal oil.
    Globes for.
    Wicks for.
Lead, red.
Leather, strips, for pot heads, 2¼ by 6 inches, sole.
Line construction tools. (See p. 51, this chapter.)
Line construction materials. (See p. 45, this chapter.)
Loom, circular (give inside diameter):
  ⅜-inch. .
  ¾-inch.
Lugs, for terminals (give size of hole for conductor).
Magneto, testing set, lineman's.
Map measurers, watch style.
Matches, wind, boxes.
Megaphones. (See p. 89, this chapter.)
Molding, type A. (See p. 70, this chapter.)
Molding, type B. (See p. 70, this chapter.)
Mortars.
Motor generators:
  ½-kilowatt direct-current motor (for charging a 15-cell telephone storage battery).
  1-kilowatt direct-current motor (for charging a 15-cell telephone storage battery).
  Ringing, direct-current motor (for use in connection with telephone switchboards).
    NOTE.—These machines can be furnished with either direct-current or alternating-current motors. When requesting alternating-current equipment give voltage, frequency, and number of phases. In requesting any parts give manufacturer's name, type, serial number, size, and all other data usually shown on name plate of the machine for which the parts are required.
    Maintenance parts—
      Bellows for.
      Brushes, generator side (give accurate dimensions).
      Brushes, motor side (give accurate dimensions).
      Bushings, porcelain, for brush holders.
Motor, starting box. (Repair parts may be had for any of the motor starters furnished by the Signal Corps. In requesting these parts give manufacturer's name, type, size, and serial number; also state fully the part desired in order to obviate mistakes.)
Mountings, buzzer, target range.
Mountings, retardation coil.
Mucilage, bottles, quarts.
Muslin, bleached, yards.
Nail puller.
Nails (give size and, if wire nails, state whether common, finishing, or brad nails are required).
Oil, dynamo.
Oiling sets, complete.
Ozite.

Pads, hand, leather.
Paint:
  Mogul, preservative. (See p. 71, this chapter.)
  Ready-mixed oil colors.
Panel:
  Telephone, power, style 1.
  Telephone, power, style 3.
  Station switch, without mountings.
Paper:
  Carbon, sheets.
  Legal cap, reams.
  Letter, typewriter, heavy, reams.
  Letter, typewriter, light, reams.
Paraffin, pounds.
Pasters, splicing, 2-inch.
Paulins, for wire carts.
Pencils:
  Copying.
  Lead.
Penholders.
Pens, gross.
Photography. (See p. 72, this chapter.)
Pick, 7-pound, with handle.
  Handle for.
Pikes, wire. (See p. 89, this chapter.)
  Hooks for.
  Poles for.
Pins, cones.
Pins, insulator, for cross arms, 1½-inch.
Pipes, sewer flush, with cast-iron covers.
Pistols, Very.
  Cartridges for, red, green, or white (see Cartridges).
Pliers:
  5-inch, side cutting.
  8-inch, side cutting.
Plow.
Plugs, insulator, for iron poles, oak, 2-inch.
Poles, lance. (See p. 89, this chapter.)
  Insulators for (clamp or pigtail).
Poles, telegraph:
  Steel.
  Wood (state height required).
Psychrometer, sling.
Radio equipment:
  Table set, ¼ kilowatt, without generator.
    Component parts for—
      Ammeter, 0–4 amperes.
      Angles, set of 8.
      Blocks, wooden, set.
      Box, motor starting.
      Bushings, hard rubber, set of 9.
      Button, push.
      Buzzer, test.

Radio equipment—Continued.

Table set, ½ kilowatt, without generator—Continued.

Component parts for—Continued.

Condenser.
Cover, canvas.
Crystals, for detector.
Gaps, spark.
Key, sending.
Padlock and hasp.
Receiver, telephone, double head.
Receiving set, complete.
Rods, high resistance.
Switch, control.
Switch, lightning.
Switch, snap.
Table.
Transformer, oscillating.
Transformer, power.

Motor generator, alternating-current motor.

Motor generator, direct-current motor.

Radio pack sets, model 1915, consist of the following *units:*

1 operating chest.
1 hand generator.
1 mast, type F.
1 pack frames, set.
1 tent.

Each *unit* contains *component parts* as follows:

Operating chests—

1 chest.
1 resonance transformer.
1 condenser.
1 oscillation transformer.
1 sending key.
1 spark gap.
1 hot-wire ammeter.
1 switch.
1 receiving set.
1 connecting cord for generator (4-conductor, with plugs).
1 connecting cord, with plug, for antenna.
1 double-head receiver.
1 test buzzer.
1 tool kit.
1 extra section for transformer secondary.
1 extra set crystals.
1 canvas case for receiver.
1 connector, 4-wire (lower half), generator.
2 connectors, 2-wire (lower half), antenna and counterpoise.
1 flexible connector for antenna inductance.[1]
1 connector, 2-wire, small, for receiving set.[1]
2 spring hooks.[1]
4 legs for chest.[1]

[1] Supplied with model 1915 chest only.

Radio equipment—Continued.
  Each *unit* contains *component parts* as follows—Continued.
    Operating chests—Continued.
      1 copy "Radiotelegraphy" (S. O. Cir. No. 1, 1914, revised).
    Hand generator—
      1 generator.
      2 cranks.
      1 stand.
      1 speedometer (carried in operating chest).
      1 cap for speedometer opening.
      1 canvas hood.
    Mast, type F. (Type D mast has 1 top, 1 bottom, 5 intermediate and 3 extra sections.)—
      1 top section.
      1 bottom section.
      8 intermediate sections.
      4 intermediate sections, extra (3 for tent).
      1 antenna.
      1 counterpoise.
      9 carriers, wire.
      4 pins, antenna.
      2 hammers.
      1 set adapters for tent (4 pieces).
      1 bag, antenna, and counterpoise.
      1 bag, accessories.
    Pack frames, set—
      3 frames (1 set). Each frame is complete with cincha, 2 straps with snap hooks, and 2 plate staples.
    Tent—
      1 tent.
      14 pins.
      2 guy ropes.
      1 insulating device.
  Complete radio pack sets are designated as *Radio pack sets, complete* (*year and serial number*). Incomplete pack sets will not be designated as such.
  Units which are complete are designated under *Unit* headings given above.
  Units which are incomplete are designated under *Component part* headings given above.
  The model, year, and serial number will always be shown in connection with operating chests and hand generators. With masts the type will be noted.
Rectifiers. (All data upon manufacturer's name plate must be given in requesting any parts.)
Rectifiers, mercury arc, G. E., complete with transformer.
Reels:
  Pay-out (Barrow type, with straps)—
    Straps, shoulder, for.
  Take-up.
  Hand, for buzzer wire—
    Cranks for, complete with pinions.

Relays:
  Pocket, 150-ohm.
  Standard, 150-ohm.
  Box-sounding, 150-ohm.
Retardation coil.
Ribbons, typewriter.
Rings:
  Cable (see hangers).
  Bridle, enameled (see p. 71, this chapter, for description)—
    Sizes $\frac{3}{8}$ to 3 inches—
      $\frac{5}{8}$-inch.
      $1\frac{1}{4}$-inch.
Rockets:
  Sequence.
  Yellow-smoke.
Rods, ground (see p. 71, this chapter):
  Terminal, for cord, type C.
    Type A, $\frac{5}{8}$-inch by 5 feet.
    Type B, $\frac{1}{2}$-inch by 6 feet.
  Guy, $\frac{5}{8}$-inch by 7 feet.
Rope, manila (all standard sizes):
  Weights, approximate, per coil of 1,200 feet—
    $\frac{1}{4}$-inch diameter, 24 pounds.
    $\frac{3}{8}$-inch diameter, 31 pounds.
    $\frac{1}{2}$-inch diameter, 95 pounds.
    $\frac{5}{8}$-inch diameter, 160 pounds.
    $\frac{3}{4}$-inch diameter, 200 pounds.
    $\frac{7}{8}$-inch diameter, 270 pounds.
    1-inch diameter, 325 pounds.
    $1\frac{1}{4}$-inch diameter, 505 pounds.
    $1\frac{1}{2}$-inch diameter, 725 pounds.
Rubber, pure (cable splicing).
Sandpaper, No. 00 to No. 4.
Saws, crosscut, carpenter's, 28-inch.
Screw anchors. (See p. 72, this chapter.)
Screw drivers:
  8-inch.
  10-inch.
Screws:
  Lag, $\frac{3}{8}$ by 4 inches (for securing brace to pole).
  Lag, $\frac{1}{2}$ by 4 inches (for securing brace to pole).
  Machine, assorted sizes and kinds.
  Wood, assorted sizes and kinds.
Seats, pole.
Sets, switch-key.
Shellac, orange.
Shells:
  Red.
  Smoke.
  White.
Shovels:
  Long-handled.
  Short-handled, round point.

Shields, expansion.
Signals, firing:
- Battery commander.
- Mortar pit.

Sleeves:
- McIntyre, copper, splicing (give size of wire)—
  - For No. 8 wire, B. & S.
  - For No. 10 wire, B. & S.
  - For No. 12 wire, B. & S.
  - For No. 14 wire, B. & S.
- Galvanized iron, splicing (give size of wire)—
  - For No. 8 wire, B. W. G.
  - For No. 9 wire, B. W. G.
  - For No. 12 wire, B. W. G.
  - For No. 14 wire, B. W. G.
- Paper, splicing—
  - ⅛ by 3 inches.
  - 3/16 by 3 inches.
- Lead, splicing (give inside diameter and length)—
  - 1 inch inside diameter (2 pounds per foot)
  - 1¼ inches inside diameter (2½ pounds per foot).
  - 1½ inches inside diameter (3½ pounds per foot).
  - 1¾ inches inside diameter (4 pounds per foot).
  - 2 inches inside diameter (4¾ pounds per foot).
  - 2½ inches inside diameter (4.8 pounds per foot).

Slide rule, atmosphere.
Solder (see p. 71, this chapter, for description):
- Half and half.
- Resin core.
- Wiping.

Soldering kits.
Solderall, or Weldall, tubes, size No. 2.
Sounders, main-line.
Spectacles, smoked (in case).
Splicing materials. (See p. 44, this chapter.)
Springs, hook-retaining.
Staples:
- Blake, insulating, No. 5.
- Galvanized iron (all standard sizes; give size required).

Stearine.
Steps, pole, galvanized iron, ⅝ by 10 inches.
Strand, messenger. (See Wire.)
Straps, pipe (give size required).
- ¼-inch (43 to the pound).
- ⅜-inch (35 to the pound).
- ½-inch (27 to the pound).
- ¾-inch (20 to the pound).
- 1-inch (17 to the pound).
- 1¼-inch (13 to the pound).
- 1½-inch (13 to the pound).
- 2-inch (5 to the pound).
- 3-inch (5 to the pound).

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Strips:
  Terminal, standard porcelain (12 pair).
Support, messenger:
  For iron poles.
  For wooden poles.
Switchboard. (See p. 73, this chapter.)
Switchboard, camp telephone. (See p. 76, this chapter.)
Switches, knife:
  S. P. S. T. (give voltage and amperes)—
    Slate base, 250-volt, 25 amperes.
  S. P. D. T. (give voltage and amperes)—
    Slate base, 250-volt, 25 amperes.
  D. P. S. T. (give voltage and amperes)—
    Slate base, 250-volt, 25 amperes.
  D. P. D. T. (give voltage and amperes)—
    Slate base, 250-volt, 25 amperes.
      (Knife switches are furnished in any number of poles and capacities required; also, fused or unfused. In requesting switches or repair parts for switches, state type and whether back or front connected.)
Switches, master:
  For 16 targets.
  For 24 targets.
Tacks, milonite, No. 18, black, brown, drab, or red.
Tags, cable, small.
Tape, insulating:
  Friction (adhesive).
  Rubber.
Telegraph set:
  Induction, complete (1912)—
    Key, sending, complete.
    Box, battery.
    Coil, induction.
    Frame, card.
    Knife switch.
    Sounders, polarized.
    Box, containing, wood (box only).
Telephones. (See p. 78, this chapter.)
Telescopes (more complete description appears on p. 41, this chapter):
  Type A. Warner & Swasey, 18 and 24 power.
  Type C. Warner & Swasey, 24 and 40 power.
  Type D. Sussfeld, Lorsch & Co., 33, 35, and 40 power.
  Type E. Warner & Swasey, 18 power.
  Type G. Lord Bury type, 24, 30, and 40 power.
Terminals:
  Carbons for.
  Cook, can-top (fused and unfused), sizes 10 to 52, pairs—
    10-pair, fused.
    10-pair, unfused, M-4.
    52-pair, fused.
  Fuses, type A-7, for.

Thermometers:
- Acid, 12-inch, unmounted.
- Mercurial.

Thimbles, guy (state size of strand for which required), $\frac{3}{8}$-inch.

Time interval:
- Apparatus, motor-driven (1912).
- Bells, large.
- Bells, small.
- Switch panel.

Torches, gasoline, small.

Trucks, lance. (See Wagons.)

Tubes, porcelain, unglazed (give size and length desired):
- $\frac{3}{8}$ inch by 4 inches.
- $\frac{3}{8}$ inch by 10 inches.
- $\frac{1}{2}$ inch by 4 inches.
- $\frac{1}{2}$ inch by 6 inches.
- $\frac{1}{2}$ inch by 10 inches.
- $\frac{5}{8}$ inch by 6 inches.
- $\frac{5}{8}$ inch by 8 inches.
- $\frac{5}{8}$ inch by 12 inches.

Turpentine.

Twine, lacing, Barbour's, 12-strand.

Typewriters.

Vane, wind.

Varnish:
- Hard-oil finish.
- Spar.

Voltammeter, portable, triple range, Weston, No. 280, 3–15–150 volts, 3–15–30 amperes, with case.

Voltmeter:
- Bristol, recording.
- Portable, in leather case.
- Portable, Jagabi.
- Weston, model 280.

Voltmeters:
- 5-volt, Eldredge.
- 6-volt.

Wagons:
- Kit (quartermaster's escort).[1]
- Lance truck.
- Repair (spring-instrument type).
- Signal Corps instrument (quartermaster's escort).[2]
- Telegraph (field wagon type).[1]
- Telephone (field wagon type).[1]

Washers:
- Copper (all commercial sizes; give size required).
- Galvanized iron, round or square (all commercial sizes; give size of bolt).

Waste, cotton.

---

[1] Standard Army escort wagon.

[2] Spring wagon (ambulance), instead of escort wagon, issued to the militia, when desired, at a cost of $199.50 each. Quartermaster's escort wagons, when required by the militia, should be entered on requisition for quartermaster's supplies.

Watches, wrist, with wristlet.
  Wristlet, for wrist watch.
Wheels, spare, for wire carts.
Wire (see p. 81, this chapter):
  64 mils diameter, copper, insulated (No. 14 B. & S.).
  81 mils diameter, galvanized iron (No. 14 B. W. G.).
  Twisted pair, 45 mils diameter, copper clad (No. 17 B. & S.).
  Buzzer, on carriers.
  Counterpoise.
  Field, 11-strand.
Wire:
  Antenna, 7-strand, 32 mils (radio).
  Antenna, 7-strand, 64 mils (radio).
  Copper, bridle, 51 mils, rubber-covered, single, No. 16 B. & S.
  Copper, hard-drawn, 81 mils, No. 12 B. & S.
  Copper clad, outside distributing, twisted pair, 45 mils, No. 17 B. & S.
  Galvanized iron, 144 mils (320 pounds per mile), No. 9 B. W. G.
  Galvanized iron, 109 mils (190 pounds per mile), No. 12 B. W. G.
Wire:
  Galvanized iron, 81 mils (96 pounds per mile), No. 14 B. W. G.
  House, twisted pair, 36 mils, No. 19 B. & S.
  Messenger strand—
    ⅜-inch.
    ½-inch.
  Pothead, 36 mils, No. 19 B. & S.
Wrenches:
  Alligator, 8-inch.
  Monkey, 8-inch.
  S sets.
Zone signal equipment, complete:
  Zone signal controller, 2-magazine.
  Zone signal outlet.
  Zone signal bell, 5-inch, 32-ohm.
  Zone signal bell, 2½-inch, 32-ohm.
  Switches, push, zone return signal.
  Lamps, zone signal controller, Tungsten filament (10-watt, G–18½).
  Lamps, zone signal outlet, Tungsten filament (10-watt, S–17).

BOX, METAL, TERMINAL.

Terminal boxes are sometimes desired at distribution points of an underground cable system or where it is desired to terminate a limited number of cables without installing the large distributing frame.

Wooden terminal boxes are still furnished in special instances, but the latest standard terminal box is constructed of sheet metal.

The first metal terminal boxes were installed in connection with the standard fire control system, coast defenses of Chesapeake Bay. These boxes are of stamped-steel construction and consist of two separate parts, the box proper for containing the terminal strips and cross connections and apron for protecting the cable potheads. The boxes are of the two-terminal strip size only, it being the intention to install two or more side by side if a greater terminal strip capacity is required.

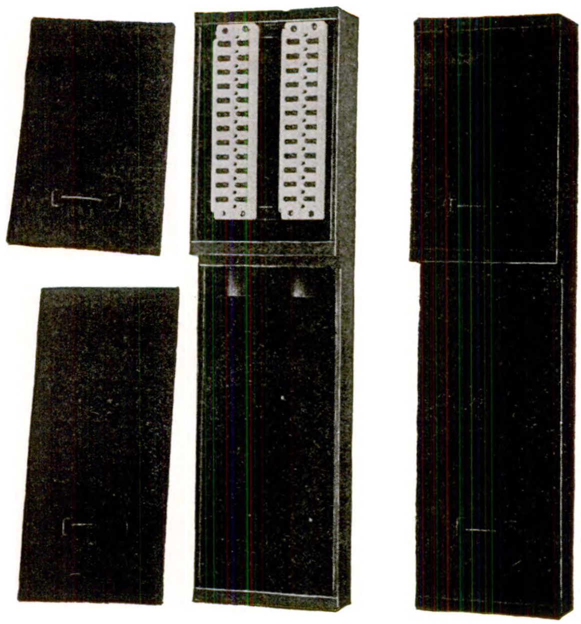


Fig. 8–1.—BOX, METAL, TERMINAL, 1915 MODEL.

Part No.	Name.	Reference No.
1	Box, complete (give strip capacity)	
2	Box, door for	
3	Box, apron door for	

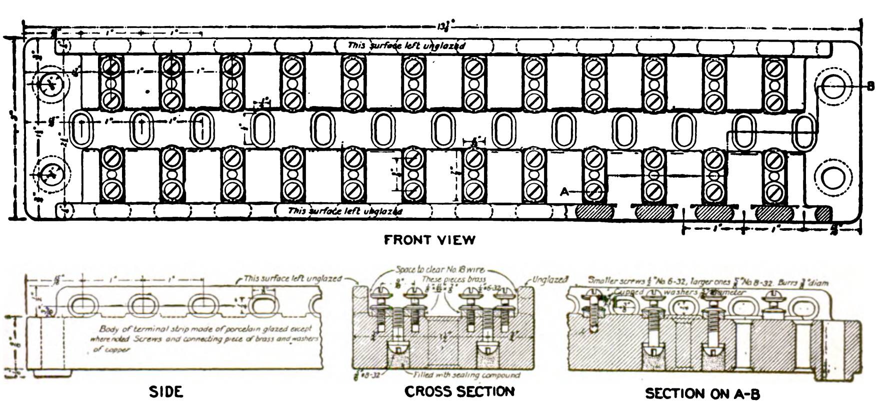


Fig. 8–2.—STRIP, TERMINAL, STANDARD.

A new metal terminal box has been designed. This terminal box is constructed of No. 18-gauge sheet steel, the box proper and apron for housing pothead being combined. This box will be furnished in three sizes, namely, two-strip, four-strip, and eight-strip, respectively, and while it is believed that these three sizes will meet the usual needs of the service, any one of the sizes may be installed in combination with either of the other two sizes.

The two-strip size may be used for either one or two strips, holes being provided for placing the terminal strip in center of box when the one-strip size is desired. The principal features of the new type of box are as follows:

The cross piece supporting the lower door at bottom may be conveniently removed and replaced. This is thought to be very desirable, especially in the larger sizes, when pot heading cables is in progress. The terminal box proper is equipped with a bottom with apertures for brass tubes through which the cables or pot heads of cables enter the main terminal box. It is intended that these tubes shall be closed by means of sealing compound, it being necessary to place a disk of wood or other material in those not in use, before sealing. For those in use, excess space should be closed with waste or oakum before pouring the compound. This feature is believed to be very important, inasmuch as heavy leakage has previously occurred in terminal boxes not so equipped, due to the warm air from duct line entering the main portion of terminal box and there condensing when atmospheric changes have occurred. Entrances for the house wires have been provided by means of one slot in center of top of box of the one and two strip size and two or more in the other two sizes. Boxes will be furnished with these slots closed by means of a small piece of metal clamped to the box with machine screws, it being intended that those slots not in use will remain closed by this means, and that those in use will be covered by the molding through which wires are led to the box.

Figure 8–1 shows the one and two strip size, the four and the eight strip size differing only in the horizontal dimension as far as size is concerned.

Figure 8–2 shows construction of the Signal Corps standard terminal strip which is invariably used with the metal terminal boxes.

BELLS, EXTENSION, LOUD RINGING.

The extension bell, loud ringing, is installed as an extension to the ringer (call bell) of a telephone when telephone is installed where noise interferes with hearing of the telephone ringer or where it is desired to hear a call distant from telephone. The type issued by the Signal Corps is weatherproof and is equipped with 6-inch gongs and a 2 m. f. condenser. The condenser is connected in series with magnet windings which are wound to a total resistance of 2,500 ohms (each magnet 1,250). These bells should be connected in parallel with the telephone line circuit, the condenser preventing the operation of signal at common battery switchboard should the telephone be connected to such an apparatus. Figure 8–3 illustrates the extension bell, loud ringing. Small extension bells are furnished for indoor use.

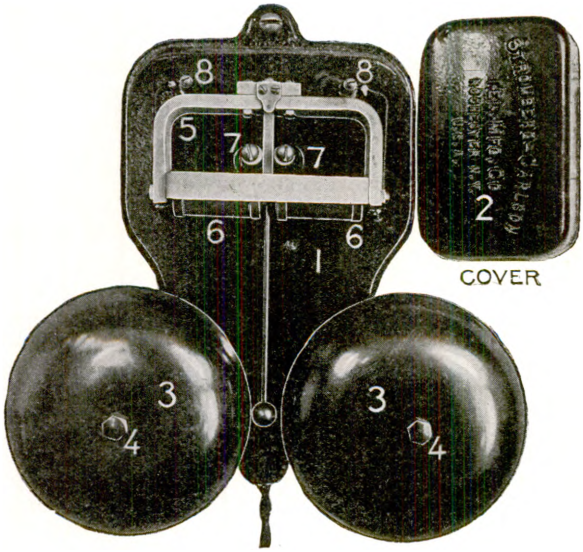


Fig. 8-3.—BELL, EXTENSION, LOUD RINGING.

Part No.	Name.	Reference No.
1	Base	1
2	Cover	2
3	Gong	3-3
4	Gong, cap nut for	4-4
5	Permanent magnet	5
6	Electromagnet	6-6
7	Adjusting eccentric, with screw	7-7
8	Binding post	8-8
9	Condenser	....

SIGNAL CART.

For transporting in the field a large assortment of signaling equipment the Signal Corps has recently designed and constructed a vehicle termed "Signal cart". This cart is arranged to be drawn by one horse or mule and can be closed to protect contents from the elements. The interior is equipped with partitions suitably arranged for separating and holding rigidly in place the following signaling equipment which forms a complement:

2 axes, hand lineman.
8 batteries, tungsten, type A.
18 books, field message.
2 buckets, water, canvas.
25 candles, lantern.
60 cartridges, Very, green.
60 cartridges, Very, red.
60 cartridges, Very, white.
2 cases, map.
16 charges, carbide.
4 compasses, pocket.

4 disks, cipher.
200 envelopes, message.
3 erasers, rubber.
4 flashlights, Ever Ready.
6 glasses, field, type EE.
4 heliographs, complete.
4 kits, flag, 2-foot.
4 kits, flag, 4-foot.
2 kits, inspectors, pocket.
4 lanterns, field, acetylene.
4 lanterns, candle, folding.
24 matches, wind, boxes.
24 pencils, lead.
4 pistols, Very.
12 rockets, sequence.
12 rockets, yellow smoke.
4 spectacles, smoked, with cases.

Figure 8–4 shows the arrangement of the signal cart.

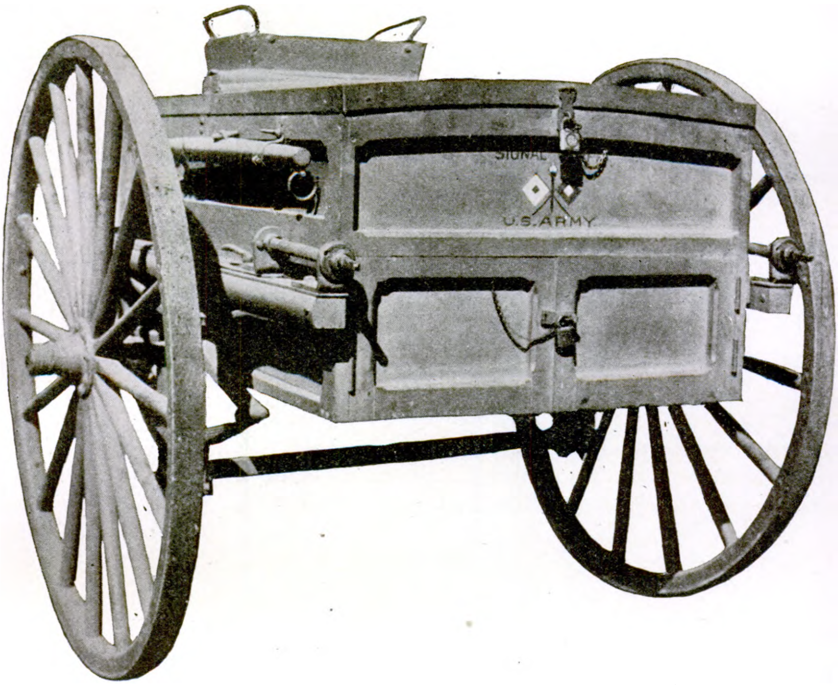


Fig. 8–4.—CART, SIGNAL.

CABLE.

For general description, illustrations, manner of splicing and installation of cable, cable systems and tables of only latest approved types, the reader is referred to Chapter 4 of this manual. Fort lists of all cables used to date by Signal Corps and detailed characteristics of each type, the following tables should be examined. It will be noted that latest approved types are also indicated in these tables.

TYPES.

For convenience the Signal Corps cables manufactured to date may be divided into six classes, viz:

Rubber insulation, submarine, serial type Nos. 1 to 200.
Rubber insulation, subterranean, serial type Nos. 201 to 300.
Paper insulation, armored, serial type Nos. 301 to 400.
Paper insulation, aerial, unarmored, serial type Nos. 401 to 500.
Special types, serial type Nos. 501 to 600.
Power cables, serial type Nos. 601 to 700.

Description of types of rubber-insulation submarine cables.

Type No.	Specification No.	Designation.	Date.	Conductor.			Diameter over insulation.	Armor wire, diameter in mils.
				Number.	Strand.	Diameter of each strand in mils.	In.	
1	......	1-conductor, deep-sea, Philippines	1899 1900	....	7 7	28.5 20.1	$\frac{9}{32}$ $\frac{8}{32}$	81 81
2	......	1-conductor, shore end, Philippines	1889 1900	....	7 7	20.1 20.1	$\frac{8}{32}$ $\frac{8}{32}$	162 162
3	1	1-conductor, deep-sea, Philippines	1899 1900	....	7	28.5	$\frac{9}{32}$	102 91
4	9	1-conductor, experimental, light	1901	......	7	20.1	$\frac{6}{32}$	51
5	10	2-conductor	1901	......	7	28.5	$\frac{9}{32}$	182
6	7	5-conductor, 1-pair, 3-straight	1901	2 3	7 7	28.5 20.1	$\frac{8}{32}$ $\frac{6}{62}$	144
7	7	7-conductor, 2-pair, 3-straight	1901	4 3	7 7	28.5 20.1	$\frac{8}{32}$ $\frac{6}{32}$	182
8	7	9-conductor, 3-pair, 3-straight	1901	3 6	7 7	28.5 20.1	$\frac{8}{32}$ $\frac{6}{32}$	204 ......
9	7	11-conductor, 4-pair, 3-straight	1901	3 8	7 7	28.5 20.1	$\frac{8}{32}$ $\frac{6}{32}$	229 ......
10	7	13-conductor, 3-straight, 5-pair	1901	3 10	7 7	28.5 20.1	$\frac{8}{32}$ $\frac{6}{32}$	229 ......
11	7	17-conductor, 7-pair, 3-straight	1901	3 14	7 7	28.5 20.1	$\frac{8}{32}$ $\frac{6}{32}$	229 ......
12	15	1-conductor	1902	......	7	28.5	$\frac{8}{32}$	128
13	16	3-conductor, San Francisco	1902	......	7	28.5	$\frac{8}{32}$	114 229
14	17	4-conductor, New London	1902	......	7	28.5	$\frac{9}{32}$	144
15	17	2-conductor	1902	......	7	28.5	$\frac{9}{32}$	144
16	17	1-conductor	1902	......	7	28.5	$\frac{9}{32}$	102
17	2	1-conductor, Int., Alaskan	1903	....	1 9	51 22.6	$\frac{8}{32}$	162
18	3	2-conductor, Int., Alaskan	1903	....	1 9	51 22.6	$\frac{8}{32}$	162
19	4	1-conductor, rock, Alaskan	1903	....	1 9	51 22.6	$\frac{8}{32}$	162 325
20	5	1-conductor, shore end, Alaskan	1903	....	1 9	51 22.6	$\frac{8}{32}$	162 258
21	6	1-conductor, deep-sea, Alaskan	1903	....	1 9	51 22.6	$\frac{8}{32}$	91
22	14	F. C., Portland, 4-pair	1903	......	7	20.1	$\frac{6}{32}$	162
23	14	F. C., Portland, 4-pair, and 4-straight	1903	4 8	7 7	28.5 20.1	$\frac{8}{32}$	204
24	14	F. C., Portland, 2-pair, and 4-straight	1903	4 4	7 7	28.5 20.1	$\frac{6}{32}$	144
25	14	F. C., Portland, 3-pair, and 3-straight	1903	2 7	7 7	28.5 20.1	$\frac{6}{32}$	162
26	14	4-pair, 3-straight	1903	3 8	7 7	28.5 20.1	$\frac{6}{32}$	204
27	14	4-pair, 4-straight	1903	9 3	7 7	28.5 20.1	$\frac{6}{32}$	204
28	14	2-pair	1903	......	7	20.1	$\frac{6}{32}$	120
29	338	1-conductor, F. C	1905	......	7	28.5	$\frac{8}{32}$	120
30	338	2-pair, F. C	1905	......	7	20.1	$\frac{7}{32}$	120
31	338	3-pair, F. C	1905	......	7	20.1	$\frac{7}{32}$	144
32	338	4-pair, F. C	1905	......	7	20.1	$\frac{7}{32}$	162
33	338	5-pair, F. C	1905	......	7	20.1	$\frac{7}{32}$	204
34	338	6-pair, F. C	1905	......	7	20.1	$\frac{7}{32}$	204

(Continued on next page.)

Description of types of rubber-insulation submarine cables—Continued.

Type No.	Specification No.	Designation.	Date.	Conductor.			Diameter over insulation.	Armor wire, diameter in mils.
				Number.	Strand.	Diameter of each strand in mils.	*In.*	
35	330	1-conductor, deep-sea, Alaskan	1905	....	1 9	51 22.6	$\frac{9}{32}$	91
36	331	1-conductor, Int., Alaskan	1905	....	1 9	51 22.6	$\frac{9}{32}$	162
37	332	1-conductor, shore end, Alaskan	1905	....	1 9	51 22.6	$\frac{9}{32}$	162 258
38	333	1-conductor, deep-sea, Philippines	1905	.....	7	28.5	$\frac{9}{32}$	128
39	333	1-conductor, shore end, Philippines	1905	.....	7	28.5	$\frac{9}{32}$	128 204
40	334	1-conductor, special, light	1905	.....	7	20.1	$\frac{7}{32}$	51
41	338	2-conductor, F. C	1905	.....	7	20.1	$\frac{7}{32}$	120
42	374	3-pair, special	1905	.....	7	28.5	$\frac{8}{32}$	144
43	375	3-pair special	1905	.....	7	28.5	$\frac{8}{32}$	144 229
[a]44	419	1-conductor, intermediate	1906	.....	7	32	$\frac{9}{32}$	162
[a]45	420	1-conductor, deep-sea	1906	.....	7	32	$\frac{9}{32}$	91
46	421	1-conductor	1906	.....	7	32	$\frac{9}{32}$	91, 162
47	424	1-conductor, Philippines	1906	.....	7	32	$\frac{9}{32}$	128
[a]50	431	1-conductor	1906	.....	7	28.5	$\frac{15}{64}$	144
[a]51	431	2-conductor	1906	.....	7	28.5	$\frac{15}{64}$	144
[a]52	431	4-conductor	1906	.....	7	28.5	$\frac{15}{64}$	162
[a]53	431	6-conductor	1906	.....	7	28.5	$\frac{15}{64}$	204
[a]54	431	8-conductor	1906	.....	7	28.5	$\frac{15}{64}$	204
[a]55	431	10-conductor	1906	.....	7	28.5	$\frac{15}{64}$	229
[a]56	431	12-conductor	1906	.....	7	28.5	$\frac{15}{64}$	229
57	431	1-conductor, double armor	1906	.....	7	28.5	$\frac{15}{64}$	144 229
58	431	2-conductor, double armor	1906	.....	7	28.5	$\frac{15}{64}$	144 229
59	431	4-conductor, double armor	1906	.....	7	28.5	$\frac{15}{64}$	162 229
60	431	6-conductor, double armor	1906	.....	7	28.5	$\frac{15}{64}$	204 229
61	431	8-conductor, double armor	1906	.....	7	28.5	$\frac{15}{64}$	204 289
62	431	10-conductor, double armor	1906	.....	7	28.5	$\frac{15}{64}$	229 289
63	431	12-conductor, double armor	1906	.....	7	28.5	$\frac{15}{64}$	229 289
64	478	1-conductor, small	1907	.....	7	28.5	$\frac{7}{32}$	51
[a]66	419	1-conductor, shore end, double armor	1915	.....	7	32	$\frac{9}{32}$	162 263

[a] Indicates approved types to be purchased in the future.

Submarine cables for deep sea are usually delivered in lengths of not less than 15 miles.

The following cables are usually furnished on reels in the following lengths:

Types, 29, 30, 41, 50, 51, and 52 in lengths of 2 miles.

Types 31, 32, 53, and 54 in lengths of 1 mile.

Types 33, 34, 55, 56, and 64 in lengths of one-half mile.

Types 57 to 63, inclusive, in special lengths.

Deep-sea single-conductor cable, as indicated in types 3, 16, and 38, will weigh approximately 3,000 pounds to the mile.

The approximate weight of the following cables per statute mile is:

	Pounds.
Type 29	2, 800
Type 30	10, 000
Type 31	12, 500
Type 32	15, 000
Type 33	21, 000
Type 34	25, 000
Type 41	6, 000

The old Alaskan cables weigh per statute mile approximately as follows:

	Pounds.
Type 35	3, 425
Type 36	5, 450
Type 37	20, 000

Description of types of rubber-insulation subterranean cables.

Type No.	Specification No.	Designation.	Date.	Conductor.		Diameter over insulation.	Armor wire, diameter in mils.	Thickness of lead sheath.
				Strand.	Diameter of each strand in mils.			
						Inch.		Inch.
201	......	1-pair	1902	......	40	$\frac{5}{32}$	......	....
202	......	3-pair	1902	......	40	$\frac{5}{32}$	......	....
203	......	5-pair	1902	......	40	$\frac{5}{32}$	......	....
204	......	6-pair, and 8-straight	1902	......	40	$\frac{5}{32}$	......	....
205	......	5-pair	1902	......	40	$\frac{5}{32}$	128	....
206	......	6-pair, and 8-straight	1902	......	40	$\frac{5}{32}$	144	....
207	12	1-pair	1902	3	22. 6	$\frac{5}{32}$	......	$\frac{1}{8}$
208	12	3-pair	1902	3	22. 6	$\frac{5}{32}$	......	$\frac{1}{8}$
209	12	6-pair	1902	3	22. 6	$\frac{5}{32}$	......	$\frac{1}{8}$
210	12	8-pair, and 8-straight	1902	3	22. 6	$\frac{5}{32}$	......	$\frac{1}{8}$
211	13	6-pair	1902	3	22. 6	$\frac{5}{32}$	128	$\frac{1}{8}$
212	13	8-pair, and 8-straight	1902	3	22. 6	$\frac{5}{32}$	144	$\frac{1}{8}$
[a]213	429	1-pair	1906	7	28. 5	$\frac{5}{32}$	......	$\frac{1}{8}$
[a]214	429	3-pair	1906	7	28. 5	$\frac{5}{32}$	......	$\frac{1}{8}$
[a]215	429	6-pair	1906	7	28. 5	$\frac{5}{32}$	......	$\frac{1}{8}$
[a]216	429	12-pair	1906	7	28. 5	$\frac{5}{32}$	......	$\frac{1}{8}$
[a]217	429	6-pair	1906	7	28. 5	$\frac{5}{32}$	128	$\frac{1}{8}$
[a]218	429	12-pair	1906	7	28. 5	$\frac{5}{32}$	144	$\frac{1}{8}$
[a]251	546	1-pair, armored, Greenfield type	......	1	40	......	Steel tape.	$\frac{1}{32}$

[a] Indicates approved types to be purchased in the future.

These rubber-insulation subterranean cables are furnished on reels, as follows:

Types 213 and 214 in one-half mile lengths.

Types 215, 216, 217, and 218 in lengths of 1,000 feet.

The weight of the standard cables per statute mile is as follows:

	Pounds.
Type 213	3, 000
Type 214	9, 200
Type 215	11, 100
Type 216	14, 785
Type 217	18, 800
Type 218	26, 900

The usual reel for the shipment of these types of cable weighs 400 pounds, has a length of 30 inches, a drum diameter of 34 inches, and sides 5 feet 6 inches high.

Types of paper-insulation armored cable.

Type No.	Specification No.	Designation.	Date.	Conductor, diameter of each strand in mils.	Insulation.	Armor wire, diameter in mils.	Thickness of lead sheath.
							Inch.
301	8	10-pair	1901	36	Double, paper	144	$\frac{1}{8}$
302	129	25-pair	1904	36	do	144	$\frac{1}{8}$
303	174	20-pair, combination	1904	8-pair, 36; 12-pair; 3-strand, 28.5	do	120	$\frac{1}{8}$
304	174	25-pair, combination	1904	10-pair, 36; 15-pair; 3-strand, 28.5	do	120	$\frac{1}{8}$
305	339, 427	5-pair	1905, 1908	36	do	120	$\frac{1}{8}$
306	339, 427	10-pair	1905, 1908	36	do	120	$\frac{1}{8}$
307	339, 427	15-pair	1905, 1908	36	do	120	$\frac{1}{8}$
308	339, 427	20-pair	1905, 1908	36	do	144	$\frac{1}{8}$
309	339, 427	25-pair	1905, 1908	36	do	144	$\frac{1}{8}$
310	339, 427	30-pair	1905, 1908	36	do	144	$\frac{5}{32}$
311	339, 427	50-pair	1905, 1908	36	do	204	$\frac{5}{32}$
312	237, 427	5-pair	1905, 1908	36	do		$\frac{1}{8}$ and $\frac{5}{32}$
313	237, 427	10-pair	1905, 1908	36	do		$\frac{1}{8}$ and $\frac{5}{32}$
314	237, 427	15-pair	1905, 1908	36	do		$\frac{1}{8}$ and $\frac{5}{32}$
315	237, 427	25-pair	1905, 1908	36	do		$\frac{1}{8}$ and $\frac{5}{32}$
316	237, 427	30-pair	1905, 1908	36	do		$\frac{1}{8}$ and $\frac{5}{32}$
317	237, 427	50-pair	1905, 1908	36	do		$\frac{1}{8}$ and $\frac{5}{32}$
318	372	5-pair, special	1905	36	do	144	$\frac{1}{8}$
319	373	do	1905	36	do	144, 204	$\frac{1}{8}$
320	427	5-pair	1906	36	do	204	$\frac{1}{8}$
[a]321	427	10-pair	1906	36	do	204	$\frac{1}{8}$
322	427	15-pair	1906	36	do	204	$\frac{5}{32}$
[a]324	427	20-pair	1906	36	do	229	$\frac{5}{32}$
[a]325	427	25-pair	1906	36	do	229	$\frac{5}{32}$
[a]326	427	30-pair	1906	36	do	229	$\frac{5}{32}$
[a]327	427	50-pair	1906	36	do	229	$\frac{5}{32}$

[a] Indicates approved types to be purchased in the future.

The armored paper-insulation cables are supplied under certain conditions for submarine work. They may also be used for subterranean work.

Type 303 weighs 22,600 pounds per statute mile.

Type 304 weighs 25,000 pounds per statute mile.

Types 303 and 304 when shipped in mile lengths are provided with reels weighing 5,000 pounds, having a length of 7 feet, a diameter of side of 8 feet, and a shaft 5 inches in diameter and 10 feet long.

These cables are usually ordered in lengths to suit the installation for which they are designed, so as to be installed without splices.

Types of double paper-insulation, lead-covered, unarmored cable.

Type No.	Designation.	Conductor, diameter of each strand in mils.	Thickness of lead sheath.	Approximate outside diameter.	Weight per statute mile.	Weight per 1,000 feet of cable and reel.
				Inches.	*Pounds.*	
a401	10-pair	36	3/32	0.722	5,370	1,186
a402	15-pair	36	3/32	.797	6,193	1,368
a403	20-pair	36	3/32	.872	7,054	1,558
a404	25-pair	36	3/32	.922	7,693	1,700
a405	30-pair	36	3/32	.982	8,416	1,860
a406	40-pair	36	7/64	1.113	11,083	2,448
a407	50-pair	36	7/64	1.208	12,445	2,750
a408	75-pair	36	7/64	1.443	15,829	3,497
a409	100-pair	36	7/64	1.638	18,860	3,967
411	10-pair	25.3	3/32	.607	4,229	935
412	15-pair	25.3	3/32	.682	4,937	1,093
413	20-pair	25.3	3/32	.737	5,549	1,226
414	25-pair	25.3	3/32	.787	6,088	1,345
415	30-pair	25.3	3/32	.827	6,520	1,441
416	40-pair	25.3	7/64	.943	8,664	1,914
417	50-pair	25.3	7/64	1.023	9,646	2,131
418	75-pair	25.3	7/64	1.193	11,890	2,627
419	100-pair	25.3	7/64	1.353	14,050	3,106

a Indicates approved types to be purchased in the future.

This cable is usually furnished on reels in lengths of 1,000 feet; length is stated in purchase order. Cable reels are usually 33 inches in length, and diameter from 56 to 72 inches.

Types of power cables (Specification 432).

Type Nos.				Area circular mils.	Number of wires in strand.	Diameter of single wires—mils.	Resistance of conductor per 1,000 feet, 68° F.	Thickness of wall of rubber insulation.	Length on reel.		Thickness of lead.	Armor wire, diameter in mils.
Single braided.	Single L. C.	Duplex L. C.	Duplex L. C. and armored.						Single braided and Single L. C.	Duplex L. C., and Duplex L. C. and armored.		
								Inch.	*Feet.*	*Feet.*	*Inch.*	
601	621	641	661	4,107	1	64.08	2.521	3/64	2,000	1,000	3/32	120
602	a 622	a 642	a 662	6,530	1	80.81	1.586	3/64	2,000	1,000	5/32	120
603	a 623	a 643	a 663	10,380	1	101.9	.9972	2/32	1,500	1,000	1/8	120
604	a 624	a 644	a 664	16,510	7	48.6	.6271	3/32	1,500	1,000	1/8	120
605	a 625	a 645	a 665	26,250	7	61.2	.3944	3/32	1,500	1,000	1/8	144
606	a 626	a 646	a 666	33,100	7	68.8	.3128	3/32	1,500	1,000	1/8	144
607	a 627	a 647	a 667	41,740	7	77.2	.2480	3/32	1,500	1,000	1/8	162
608	628	648	668	52,630	19	52.6	.1967	3/32	1,500	1,000	1/8	162
609	629	649	669	66,370	19	59.1	.1560	4/32	1,000	1,000	1/8	162
610	630	650	670	83,690	19	66.4	.1237	4/32	1,000	1,000	1/8	162
611	631	651	671	105,500	19	74.5	.09811	4/32	1,000	1,000	1/8	162
612	632	652	672	133,100	19	83.7	.07780	4/32	1,000	1,000	1/8	162
613	633	653	673	167,800	19	94.0	.06170	4/32	1,000	1,000	1/8	162
614	634	654	674	211,600	19	105.5	.04893	4/32	1,000	1,000	1/8	162

a Indicates approved types to be purchased for stock in the future.

Special types of power cable that have been purchased in the past for special purposes are as follows:

Type No. 629*a* conforms to type No. 629, with the exception that one wire, 59.1 mils in diameter, of the conductor is replaced by a potential conductor made up as follows: Conductor to consist of 16 strands copper wire, each 10 mils in diameter, having an area of 1,600 circular mils, with a serving of cotton and covered with an even layer of rubber compound to a uniform diameter of one-tenth ($\frac{1}{10}$) inch, the conductor being well centered in the insulation.

Type 643*a* conforms to type 643, except that four conductors 102 mils in diameter are supplied.

Type 663*a* conforms to type 663, except that four conductors 102 mils in diameter are supplied.

The reader is referred to chapter 4 of this manual for general information concerning cable, its installation and accountability.

SUBMARINE CABLE GEAR AND SUPPLIES.

Anchors, mushroom, ordinary. Supplied in sizes of 1, 2, 2½, 3, 4, and 5 hundredweight.

Anchors, mushroom, patent (Johnson's patent removable shank). Supplied in sizes of 1, 2, 2½, 3, 4, and 5 hundredweight.

Blocks, wood or iron. Specify whether plain or snatch type, number of sheaves, and length of block in inches.

Buoys, automatic whistling. Weight, 18 hundredweight; safe load, 25 hundredweight.

Buoys, cable. Specify length and diameter or carrying capacity desired, or both. These can be obtained in capacities from 3 hundredweight to 6 tons. Specify bridle chains for same when desired.

Boats, cable (also called cable cutters).

Blades for hacksaws; dozen. Specify length.

Chain, bridle. Usually made up in lengths as desired and fitted with egg links at each end. Necessary to specify size of links or state breaking strain. The type is usually crane chain and size is the thickness of the link. To obtain exact duplication, also specify the outside width of the link and the pitch, which is the distance between similar points of successive links.

Charts. Give serial number and specify whether Coast and Geodetic Survey or Hydrographic Office edition.

Chronometers, marine.

Clamps, buoy lamp.

Coats, oilskin.

Counters, revolution.

Core, cable, feet. For test-room connections and leads.

Couplings, for chains. Specify size and kind of coupling, whether with swivel and egg links or simply shackles.

Crinolines, cable tank. Manufactured only according to specifications for each particular case.

Cut-meter. This is a direct-reading speed indicator which can be applied to any moving surface.

Cutters, cable. A portable bolt cutter that may be mounted on a block with handles. It is supplied for use about the decks of cable ships.

Dividers, proportional.

Dividers, steel, navigator's.

Dynamometers, large size 25 tons strain, small size strains to 10 tons.

Frames, hacksaw. Adjustable furnished unless length is stated.

Gauges, wire.

Grapnels, ordinary 5-prong can be obtained in sizes of 1, 1½, 2, 2½, 2½ long prong, 3, and 3½ hundredweight.

Grapnels, boat, weight about 23 pounds.

Grapnels, Jamieson's rock, 2 types, one having flat prongs and the other with prongs forked at shank. Type with flat prongs preferred.

Grapnels, Johnson's renewable section.

Spare prongs for same, short.

Spare prongs for same, long.

Grapnels, Lucas patent cutting and holding, complete, with knives.

Grapnels, centipede, can be obtained in sizes of ½, 1, 1½, 2, 2½, 3, and 3½ hundredweight.

Grapnels, centipede, boat, weight 30 pounds.

Grapnels, Murphy's patent centipede, in sets of 6 each, consisting of 4 grapnels and 2 spare, and including 4 shackles. Can be obtained in 4 sizes, weights per section as follows: 20, 45, 55, 85 pounds each.

Hats, oilskin.

Hose, steam, flexible copper, 1½ and 2 inch sizes.

Hose, steam, 5-ply rubber, 1½ and 2 inch sizes.

Hose, steam, 8-ply rubber, wire-wound, 1½ and 2 inch sizes.

Hose couplings. Requisition for steam hose specify length of sections.

Hauling-off gear, steam or electric. For electric specify voltage.

Irons, calking, 3 per set.

Irons, soldering, electric. Specify voltage.

Knives, cable sheath.

Lamps, alcohol.

Lamps, buoy; can be obtained in various sizes. Ship's anchor-lights usually supplied. Specify size.

Lamp frames for attachment to flagstaffs and buoy tripods.

Lamps, blow. (*See* "Torches, blow.")

Lamps, incandescent. Specify voltage and candlepower. Edison sockets will be furnished unless otherwise indicated. Straight filament lamps are supplied for testing room galvanometers. Special lamps for telephoto and Ardois must have voltage and maker's name specified.

Lanterns, tin.

Lead, red, pounds. Supplied for preservation of cable gear. Unmixed will be supplied unless otherwise specified.

Leads, deck, several sizes and kinds of 1, 2, and 3 roller leads.

Leads, heaving, 12 and 28 pound weights.

Lead, sounding, for Thompson machine.

Leather, rigging, sides. Specify thickness and quality.

Logs, taffrail, with propeller and line.

Links. Specify length, width, and size.

Machines, cable, usually classed as "pick-up," "pay-out," or combined "picking-up and paying-out." To be accounted for by name of maker.

Machines, D. S., sounding, Sigsbee.

Machines, electric, vulcanizing. Specify voltage.

Mallets, calking.

Mallets, serving, wood.

Mallets, serving, iron.

Mushrooms. (*See* "Anchor, mushroom.")

Marline, spikes.

Needles, sail, dozen.

Oil, boiled linseed, gallons.

Oil, engine, barrels.

Oil, cylinder, barrels.

Padlocks. Specify make desired and size. Usually unsatisfactory when furnished assorted.

Paint. Specify whether mixed or unmixed.

Palms, sailor's sewing.

Rope, grapnel, combined wire and manila, breaking strain 15 tons; weight per thousand fathoms, exclusive of fittings, 55½ hundredweight.

Rope, grapnel and buoy, combined wire and manila, breaking strain 13½ tons; weight per thousand fathoms, exclusive of fittings, 49½ hundredweight.

Rope, buoy, combined wire and manila, breaking strain 7½ tons; weight per thousand fathoms, exclusive of fittings, 24 hundredweight. Specify the length of sections of grapnel and buoy ropes; also that each length be equipped with proper fittings.

Rope, manila, coils. Specify size, inches (circumference). Rope supplied only in units of coils. Number of feet in a coil not fixed. Three-strand will be supplied unless 4-strand is specified.

Rotometers, Elliot (revolution counters).

Scales for T.-B. sounding tubes.

Sextant.

Shackles. Specify size whether screw or pin; give size and also length and width, as some types are unsuitable for use with grapnel rope.

Sheaves. There is such a great variety of sizes and kinds that requisitions should clearly specify type and dimensions.

Spun yarn, 3 yarn.

Shots, sounding. Can be obtained in weights from 40 to 90 pounds. Should be purchased by cable ship, as required.

Splicing tool. A disk with handles for laying on armor wire.

Swivels. Can be obtained in various sizes and with various shaped links attached.

Slip-hooks (detaching hooks). Has trigger for releasing buoys. Three sizes—small, medium, and large.

Tubes, glass, sounding, for Thompson machine, 10 tubes per case.

Tubes, sounding, Tanner-Blish, for Thompson machine, frosted glass.

Tube, brass, sounding. To attach to sounding wire and contains the glass tube.

Tube boxes for T.-B. sounding tubes.

Tags, cable, linen.

Telegraphs, special. Refers to pedestal dials complete; also known as "ship's telegraph." Requisitions for chain or pulleys specify exact size, and for the telegraphs furnish a sketch showing the lettering desired for the dial.

Telephoto outfits (Ardois). To be accounted for by number.

Thermometers, deep-sea sounding. These thermometers on being reversed when heaving in indicate the bottom temperature. Negretti & Zambra type will be supplied unless otherwise indicated.

Thermometer cases. For reversing thermometer to obtain bottom temperature.

Thimbles. Can be supplied in great variety of sizes and shapes. Galvanized iron will be supplied unless otherwise specified.

Torches, blow. Gasoline type will be furnished unless otherwise specified.

Trays, vulcanizing. These are for melting paraffin for vulcanizing joints. Can not be purchased in open market. When new one is required, old one should be furnished as a sample to manufacturer.

Waste, cotton, bales, about 100 pounds per bale.

Wire, seizing. This is a soft G. I. wire, 40 mils in diameter, for serving armor of D. S. cable.

Wire, sounding, 7-strand, for Thompson machine. Supplied in lengths of 300 fathoms.

Wire, deep-sea, sounding, fathoms. This is "No. 11 music wire," approximately 28.5 mils in diameter, breaking strain about 207 pounds. Supplied in sealed tin cans containing 1,000 fathoms of wire.

Books supplied on cable testing and engineering: Deep-Sea Explorations (Fish Commission edition), Electrical Engineer's Pocket Book (Foster), Electrical Testing for Telegraph Engineers (Young), Submarine Cable Laying and Repairing (Wilkinson), Submarine Telegraphs (Bright), Submarine Cable Testing (Fisher & Darby), Electrical Testing (Kent).

WIRE CART.

Carts, wire, type L, complete (the type L wire cart, when furnished complete, is supplied with the following extra parts: 1 wheel, except in the case of Signal Corps field companies of the Regular Army, which are supplied only with the number authorized by existing orders; 1 paulin; 1 axle; 2 brake bands; bearings for 1 reel, complete; 1 crank, reel; 1 wrench, axle; 1 can, oil, steel, pint size; and 1 canvas roll containing the following tools: 1 chisel, cold, 6-inch; 1 screw driver, 5-inch; 1 screw driver, 10-inch; 1 hammer, claw, 11½ ounces; 1 wrench, monkey, 8-inch; 1 pliers, side cutting, 8-inch; 1 wrench set, S, to fit special bolts on carts; 1 wrench, alligator, 8-inch):

Maintenance parts—

- Axle, with nuts and pins.
- Band, brake, complete.
- Bearing, roller, for driving gear.
- Bearings, roller, for reel.
- Block, terminal.
- Bolt and nut, 7½ by ¾, for doubletree, with cotter-pin hole drilled in same.
- Bolt and nut, for tire, 3 by $\frac{5}{16}$.
- Bolt—
  - For axle bracket, 7½ by ⅝, slotted-head castle nut.
  - For center axle bracket, 4½ by ⅝, slotted head castle nut.
  - For countershaft hanger, 7½ by ⅝, slotted-head castle nut.
- Bolts, for wheel hub.
- Bolt, hanger, pole prop.
- Box—
  - Center axle.
  - Outer axle.
- Bracket—
  - For pole prop.
  - Plunger.
  - Rod, reel guide, center or side.
- Brake, reel, with raybestos—
  - Right.
  - Left.
- Bushing and nut, for doubletree.
- Bushing, fiber, for reel.
- Can, oil—
  - 10-inch, bent spout, copper.
  - Steel, pint size.

Carts, wire, type L, complete—Continued.
- Maintenance parts—Continued.
  - Cap—
    - Hub.
    - Roller, antifriction.
  - Chain and ring, for doubletree.
  - Chain, pole prop.
  - Clevis, for commercial reel shaft.
  - Clutch, complete, with gear (33 teeth).
  - Conductor, terminal block.
  - Connector—
    - Ground, for wheel (on spoke).
    - Inside.
    - Outside.
  - Cotter pins—
    - For axle.
    - For bolt, for axle bracket.
  - Crab, pole.
  - Doubletree.
  - Eye, conductor, terminal block.
  - Gear—
    - Countershaft, with shaft attached (69 teeth).
    - Driving (66 teeth).
    - Reel (30 teeth).
  - Handle, crank.
  - Holdback, for pole neck yoke.
  - Hub, wheel.
  - Insulator—
    - Block, for inner part of reel.
    - Block, for plunger bracket.
    - For singletree.
    - Washer, on plunger bracket.
  - Lever—
    - Brake, foot.
    - Clutch.
    - Reel brake, foot.
  - Nut, axle—
    - Left.
    - Right.
  - Paulin.
  - Pin and chain, split, for commercial reel shaft.
  - Pin, connecting, for foot lever.
  - Pins, pivot—
    - Foot lever.
    - Reel brake.
  - Plunger.
  - Pole, complete, including pole prop and bracket.
  - Pole (wood only).
  - Prop, pole.
  - Raybestos, facings, for reel brake.
  - Reel, complete, without roller bearing.
  - Ring, contact, for reel.

Carts, wire, type L, complete—Continued.
- Maintenance parts—Continued.
  - Rod—
    - Clutch connecting.
    - Connecting, brake lever.
    - Reel guide.
  - Roller, antifriction.
    - Bearing for.
  - Roll, tool, canvas, complete, with tools.
    - Case, canvas.
    - Chisel, cold, 6-inch.
    - Hammer, claw, 11½ ounces.
    - Pliers, side cutting, 8-inch.
    - Screw driver—
      - 5-inch.
      - 10-inch.
    - Wrench—
      - Alligator, 8-inch.
      - Monkey, 8-inch.
      - Set, S, to fit special bolts on carts.
  - Screw—
    - For contact ring (R. H. machine, 2-inch, 20-thread, No. 14), per gross.
    - Set, and lock nut, for center axle box.
  - Screws for reel gear.
  - Shaft reel, commercial.
  - Shaft rock—
    - Brake lever.
    - Clutch.
  - Singletree.
  - Spring, plunger.
  - Washer, fiber, for reel.
  - Wheel, complete.
  - Wrench, axle.
  - Yoke—
    - Axle, with brake-band hanger.
    - Neck.

CORDS.

Figures 8–5, 8–6, 8–7, 8–8 illustrate cords used with various apparatus supplied by the Signal Corps. Figure 8–9 illustrates terminals used in connection with the cords. The number shown for each cord is the latest number adopted and should be used in referring to the cords.

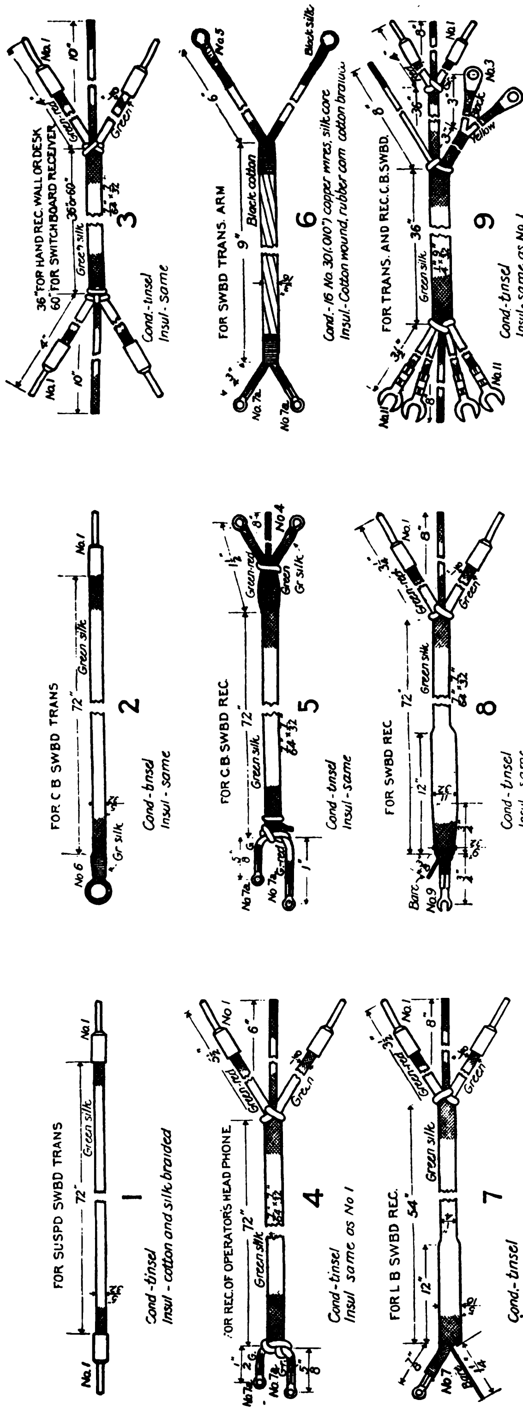


Fig. 8-5.—CORDS, STANDARD, FOR SWITCHBOARD TRANSMITTERS AND RECEIVERS.

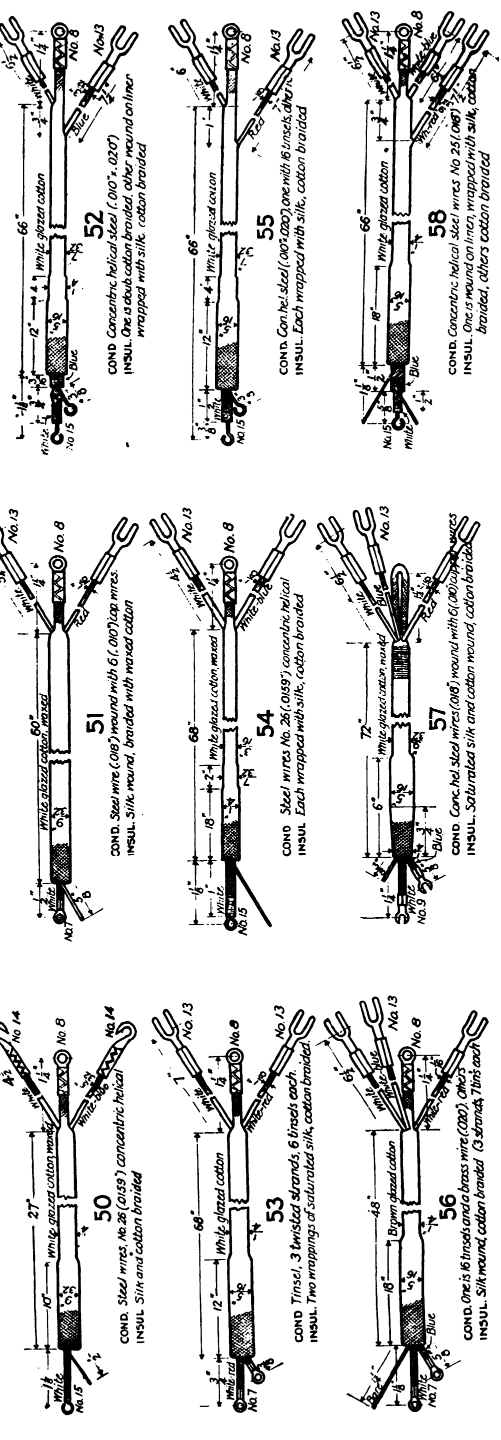


Fig. 8-6.—CORDS, STANDARD, SWITCHBOARD, CONNECTING.

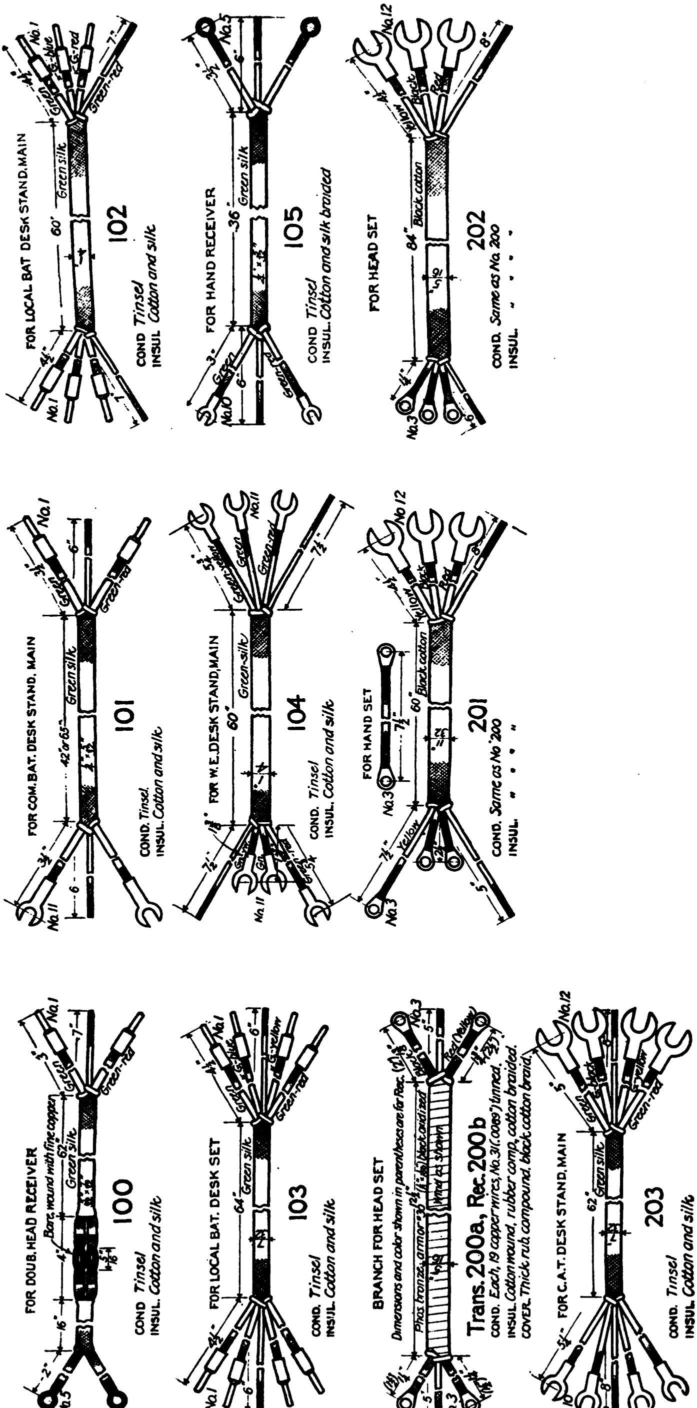


Fig. 8-7.—CORDS, STANDARD, FOR TELEPHONES, POST AND ARTILLERY TYPE

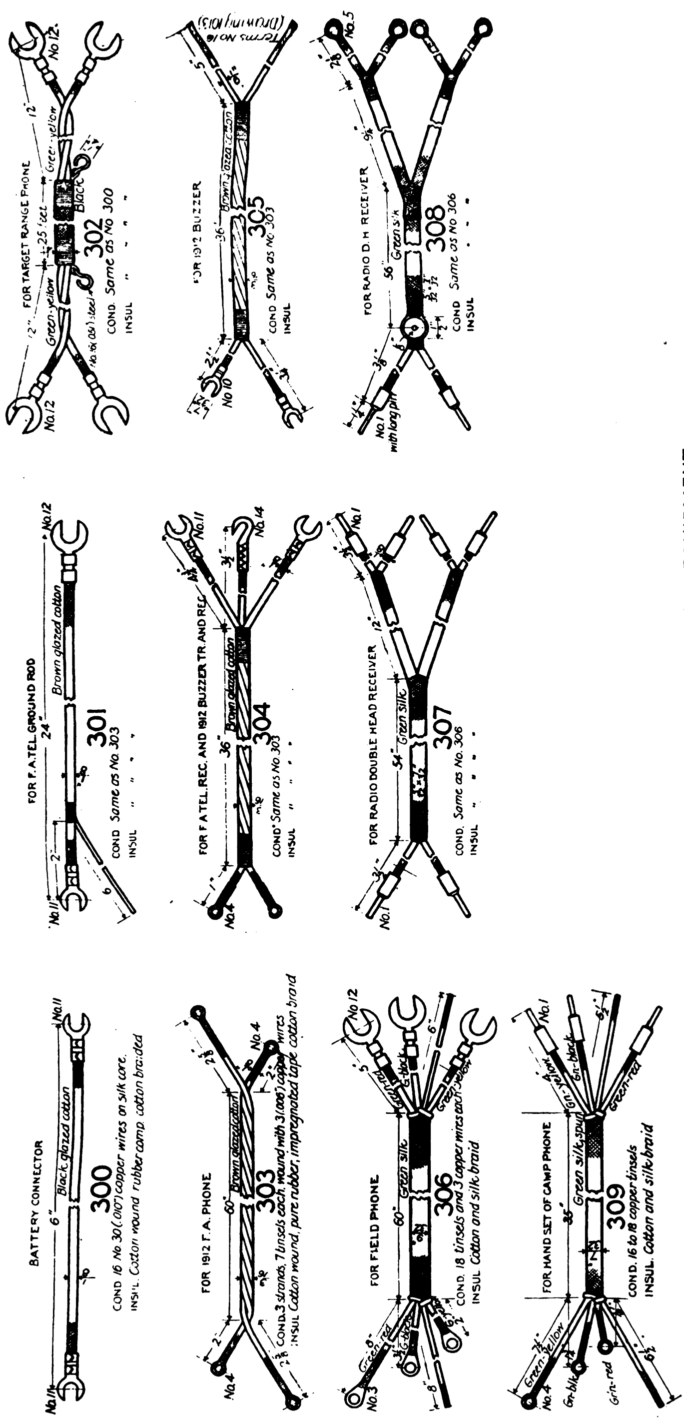


Fig. 8-8.—CORDS, STANDARD, FOR FIELD EQUIPMENT.

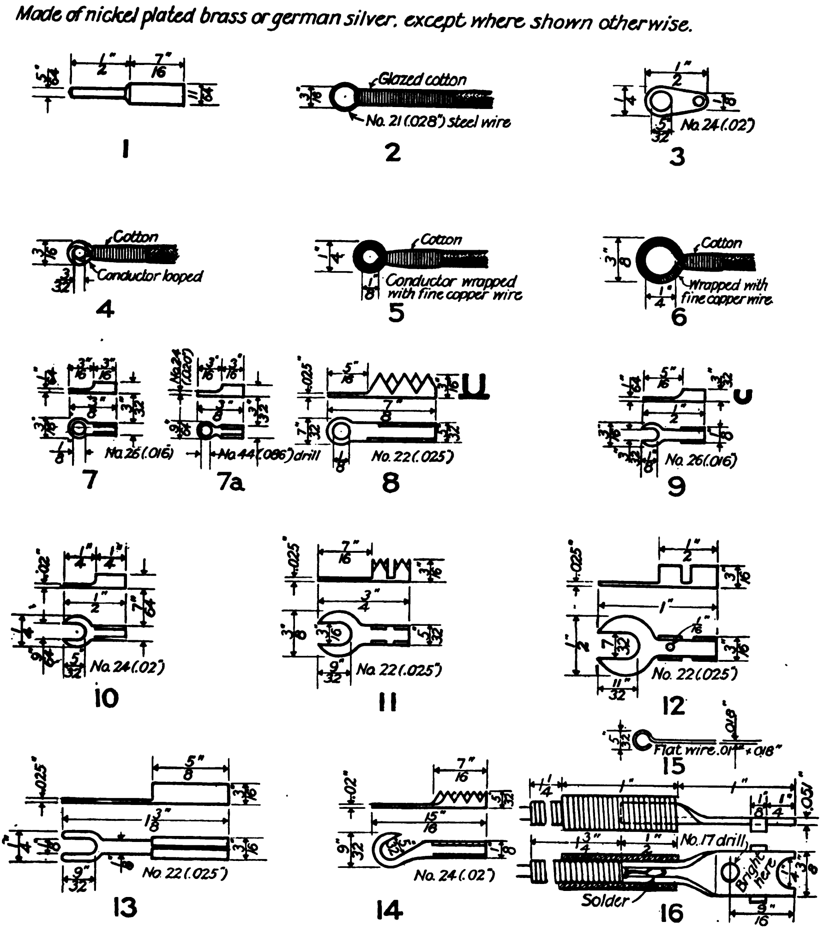


Fig. 8–9.—CORDS, STANDARD, TERMINALS FOR.

Following is a brief description of field glasses and telescopes issued by the Signal Corps.

FIELD GLASSES.

Type A "1910".—Magnification approximately 3½ and 5½ diameters; Galilean type; object lens, 1½ inches; interpupillary adjustment; tan leather finish; tan leather carrying case with compass; weight of glass complete with case, cord, and strap, 28 ounces. At a distance of 1,000 yards the field of view has a diameter of 110 yards for the 3½-power and 70 yards for the 5½-power. Length of glass closed, 4 inches. This glass is issued as a part of the visual signaling kit to companies of Coast Artillery, Infantry, and Philippine Scouts, and to troops of Cavalry. Price, $14.65.

Type B.—Magnification approximately 4½ and 6½ diameters; Galilean type; object lens, 1¾ inches; interpupillary adjustment; tan leather finish; tan leather carrying case, with compass; weight of glass, complete with case, cord, and strap, 31 ounces; length of glass closed, 4½ inches. At a distance of 1,000 yards the field of view has a diameter of 106 yards for the 4½-power and 70 yards for the 6½-power. This glass was formerly issued as a part of the fire-control equipment to Field Artillery. Price, $17.50.

Type C.—A high-power prismatic binocular, the present issue being the Terlux 10-power; object lens, 1¾ inches; interpupillary adjustment; common focus for both barrels, and one barrel equipped with independent focusing device; tan leather finish; sunshade; tan leather carrying case; weight of glass complete with case, cord, and strap, 48 ounces; length of glass closed, 7¾ inches. At a distance of 1,000 yards the field of view has a diameter of 70 yards. One glass is issued to the commanding officer of each machine-gun company and machine-gun troop. Price, $39.90.

Type D.—Prismatic binocular, the present issue being the Busch 8-power "Stellux;" object lens, ¾ inch; interpupillary adjustment; common focus for both barrels, and one barrel equipped with independent focusing device; tan leather finish; tan leather carrying case; weight of glass complete, with case, cord, and strap, 21 ounces; length of glass closed, 3$\frac{5}{16}$ inches. At a distance of 1,000 yards the field of view has a diameter of 96 yards. This glass is issued to field companies of the Signal Corps, and, on account of its excellence, light weight, and small size is especially suitable for the personal field glass of an officer who desires a high-power field glass. Price, $25.10.

Type EE.—Prismatic binocular, 6-power; object lens, 1$\frac{3}{16}$ inches; interpupillary adjustment; each barrel equipped with an independent focusing device; one barrel equipped with a mil scale; tan leather finish; sunshade; tan leather carrying case with compass; weight of glass complete, with case, cord, and strap, 41 ounces. Length of glass closed, 4$\frac{11}{16}$ inches. At a distance of 1,000 yards the field of view has a diameter of 140 yards. This glass is the approved glass for issue to Field Artillery organizations. Price, $33.75.

Officers in continental United States, Porto Rico, or Cuba making application for the purchase of field glasses should address such application to the Chief Signal Officer of the Army. Officers in the Philippine Islands or China should address applications to the Department Signal Officer, Philippine Department.

The Government does not pay transportation charges on articles sold to officers. All applications to the Chief Signal Officer of the Army should be accompanied by post-office money order drawn on Washington post-office or New York exchange for the amount, payable to "Disbursing officer, Signal Corps, United States Army." Signal Corps form No. 240, in duplicate, should accompany all applications.

Unless otherwise specified, field glasses will be shipped express charges collect, the amount of expressage being dependent on distance glasses are shipped. If insured parcel-post shipment is desired, the amount necessary for parcel postage should be included in remittance. Shipments of field glasses to points in continental United States, Porto Rico, and Cuba are made from Fort Wood, N. Y., and to points in China and the Philippine Islands from Manila, P. I. For rates relative to insured parcel post, see Signal Corps Manual No. 7, revised edition.

TELESCOPES.

Type A.—Warner & Swasey, poro-prism, complete with two eyepieces, powers 18 and 24, with alt-azimuth mounting, folding tripod, and carrying case.

Type C.—Warner & Swasey, terrestrial, 2-inch prism, two eyepieces, 24 and 40 power, complete with alt-azimuth mounting, folding tripod, and carrying case.

Type D.—Sussfeld, Lorsch & Co., Galilean, 33, 35, 40 power, leather covered, with leather caps and strap, six sections, objective, 2-inch; length closed, 9½ inches; open, 37 inches; weight, 2 pounds 4 ounces.

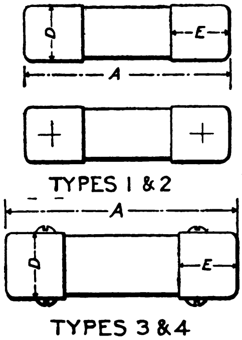
Type E-18x.—Warner & Swasey, 18 power, prismatic (now designated Artillery type), in black leather carrying case, with heavy wooden nonfolding tripod (5 feet 2 inches), one eyepiece; enameled; objective, 1$\frac{9}{16}$ inches; length closed, 12$\frac{1}{4}$ inches; open, 13$\frac{1}{2}$ inches; weight, telescope, 5 pounds 8 ounces; leather case, 1 pound 8 ounces; tripod, 8 pounds.

Type G 24, 30, 40x.—Lord Bury type, one eyepiece, 5 sections, black leather covered, with leather caps and strap, without tripod; gun metal. Objective, 1$\frac{3}{4}$ inches; length closed, 10$\frac{1}{2}$ inches; open, 33 inches; weight, 2 pounds 3 ounces; tripod, 8 pounds.

FUSES.

The standard fuses furnished by the Signal Corps in connection with fire control and post telephone systems are illustrated in figure 8–10.

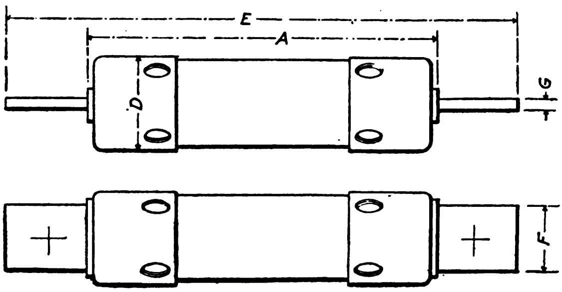
With post telephone switchboards, mica fuses similar to type 8 are used to protect lines and cord circuits. In some instances the dimensions of these fuses do not correspond with those of any of the standard Signal Corps types shown in figure 8–10. This is due to manufacturers having furnished their standard fuse mountings with the switchboard.



Amperes are Natl. Elec. Code rating

TYPE	AMPS.	A.	B	C	D	E	F	G
S.C. 1	3-15	1$\frac{1}{2}$			$\frac{13}{32}$	$\frac{13}{32}$		
" 2	3-15	1$\frac{3}{4}$			$\frac{15}{32}$	$\frac{15}{32}$		
" 3	0-30	2			$\frac{9}{16}$	$\frac{1}{2}$		
" 4	35-60	3			$\frac{13}{16}$	$\frac{5}{8}$		
" 5	65-100	4			1$\frac{1}{16}$	5$\frac{7}{8}$	$\frac{3}{4}$	$\frac{1}{8}$
" 6	110-200	4$\frac{1}{2}$			1$\frac{9}{16}$	7$\frac{1}{8}$	1$\frac{1}{8}$	$\frac{3}{16}$

Types 1 and 2 are special, 3, 4, 5 and 6 are National Elec. Code Standard.



1 AMPERE MICA *Terminals are copper*

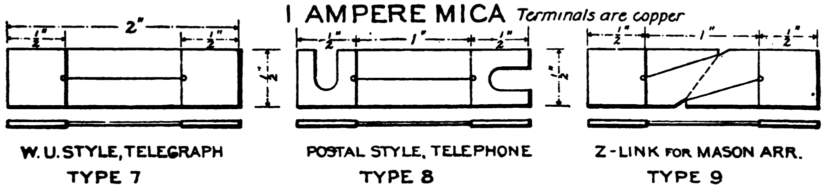


Fig. 8-10.—FUSES, STANDARD TYPES.

Those rendering requisitions for fuses should specify the Signal Corps type and the ampere capacity unless the fuses desired do not correspond with any of the types. In the event of the fuse not being standard Signal Corps issue, the apparatus with which it is to be used, name of manufacturer, and, if practicable, a sample of fuse should be furnished.

IRON CONDUIT.

Loricated iron conduit of various sizes is furnished where extra protection for plain lead-covered cable or rubber-covered wire is desired.

FIBER CONDUIT.

This is the standard conduit furnished for underground construction and is usually supplied in 5-foot lengths, 3 inches inside diameter, with ends formed for socket joint. Various sizes can be furnished, and conduit with screw socket joints instead of ordinary socket joints will be furnished if satisfactory reason be given.

KEY, STRAP.

The standard strap key of the Signal Corps is made in two sizes. They are designated "key, strap, large" and "key, strap, small." The large strap key has a slate base 5¾ by 3⅛ inches, and the small strap key has a slate base 4 by 2 inches. The principal metal parts of the two keys differ correspondingly in size.

The upper, lower, and two central contacts are of platinum wire 40 mils diameter, the upper contact being adjustable. Three substantial binding posts to which are connected the external circuits connect with the upper, lower, and central contacts, respectively. Referring to figure 8–11, it will be noted that normally the upper contact and one of the central contacts are in electrical contact, and that when the strap is depressed by means of the hard-rubber handle, this contact is broken and the other central contact and lower contact are brought in electrical contact. When the handle is released the "spring brass" strap restores the contacts to normal position. The two central contacts are not insulated from each other.

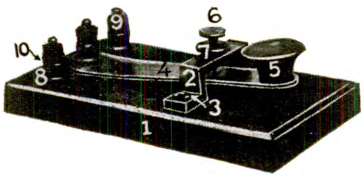


Fig. 8–11.—KEY, STRAP, LARGE.

Part No.	Name.	Reference No.
1	Base, slate, complete	1
2	Yoke, complete	2
3	Yoke, screws for fastening	3
4	Strap	4
5	Strap, hard-rubber handle for	5
6	Contact screw, upper, complete	6
7	Contact screw, upper, locking nut for	7
8	Binding post, complete	8
9	Binding post, nut for	9
10	Binding post, washer for	10
11	Contact, lower, complete	....

INSULATING AND SPLICING MATERIALS.

[This list includes both fire-control and general-service supplies. General specification No. 569 covers insulating and splicing material.]

Alcohol (grain, wood, or denatured) per gallon, as ordered.
Armalac, per gallon.
Asbestos, as ordered.
Asphaltum varnish, per gallon.
Bandages, cotton, rolls 2 inches wide by 3 yards long.
Beeswax, yellow, per pound.
Compound, Chatterton's, per pound.
Cloths, wiping, Moleskin, 3, 5, and 6 inches square.
Cloth, Crocus, per quire.
Cotton, strips, ¼-inch wide, in rolls 5 inches in diameter.
Cotton wicking, per ball.
Instrument lacquer, blue, colorless, or yellow, per bottle.
Insulatine, per pound, in 1-pound sticks.
Muslin, strong, unbleached, 2 inches wide, 10-yard rolls.
Ozite, per gallon, in 1-gallon tin cans. No. 1 or No. 2 grade.
Paraffin, per pound, flat cakes, melting point not lower than 120° F.
Paraffin oil, per quart.
P. & B. paint, No. 2, 1-gallon cans.
Pasters, gummed, paper for wiped joints, 2 inches wide, 11 or 15 inches long, sanitary, per hundred.
Rubber, pure, cut sheet, on cambric; thickness of rubber about 0.0235 inch, per pound.
Rubber, pink, 60 per cent pure Para, cut sheet, on cambric; thickness of rubber about 0.012 inch, per pound.
Rubber cement, in pint and half pint cans as ordered, specification paragraph 2 (a).
Shellac varnish, orange or white, quarts and gallons; high grades only.
Shellac gum, orange, per pound.
Sandpaper, per quire or dozen sheets, Nos. 0, 1, and 2.
Sleeves, paper, ⅛ or $\frac{3}{16}$ by 3 inches, per 100.
Sleeves, lead, 1, 1½, 2, 2½, or 3 inches diameter, 16-inch pieces or in feet, "C" weight.
Sleeves, McIntyre, give size of wire in mils.
Soft rubber tubing, $\frac{1}{16}$, $\frac{3}{16}$, and ¼-inch bore, per foot.
Solder, resin core, 5-pound spools, per pound.
Solder, half and half, in bars, per pound (50 parts tin, 50 parts lead).
Solder, plumber's wiping, in ingots, per pound (40 parts tin, 60 parts lead).
Stearine, in ¼-pound metal cans.
Tape, friction, ¾ inch wide, ¼-pound rolls, per pound, in tin boxes.
Tape, Okonite, ¼-pound rolls, per pound, in pasteboard boxes.
Twine, lacing, 1-pound balls, Barbour's "Open Hand" brand, 12 strand.

INSULATING COMPOUNDS.

In order that confusion may be avoided concerning the use of the various insulating compounds which are ordered, the following should be noted:

The compounds supplied are: Chatterton's compound (first quality), insulatine, gyite, ozite, paraffin.

Chatterton's compound.—Chatterton's compound is a high-class insulator costing $1 per pound and should be used only in sealing ends of cable where they are exposed to storage-battery fumes or in similar work where a high-quality insulator is required.

Insulatine.—Insulatine is not a high-quality insulator, and it is intended for use in sealing outlet boxes where a wall of rubber exists between the insulatine and the conductor. It should never be used for insulating purposes only, and is depended on more for its sealing qualities than for insulation. This material is comparatively cheap, costing about 12 cents per pound.

Gyite.—Is a better grade than insulatine, but not as good as ozite.

Ozite.—Ozite is used for sealing potheads in paper cable work. It may also be used for sealing the ends of rubber cable.

No. 1 ozite is hard, No. 2 is medium soft, and No. 3 is soft, at approximately 60° F. In ordering state the purpose for which the material is desired and the conditions as to temperature.

Paraffin.—Paraffin is intended for use in boiling out splices in paper insulation cable and in drying the ends. It should never be used in pothead work or for sealing purposes.

LINE CONSTRUCTION MATERIALS.

[This list includes both fire-control and general-service supplies.]

Anchors, guy, D. & T., 8-inch.
Anchors, star, 1⅝-inch, No. 10.
Anchors, star, ⅜-inch, composition.
Anchors, expansion, ½-inch, composition.
Anchors, guy, Matthews, 6-inch or 8-inch, with rods.
Arresters, "Cook":
 Can top, type M–8, unfused.
 Can top, type S–8, fused.
Arresters, Mason's Standard, with or without fuses.
Arresters, "Sterling," in strips of 5 or 10 pair, fused, with carbon arresters.
Brackets, oak.
Bolts, cross-arm, diameter ⅝-inch; supplied in six lengths; 10, 12, 14, 16, 18, and 20 inches.
Bolts for cross-arm braces, carriage, ⅜ inch by 4 inches long.
Bolts, double-arm (diameter ½ inch; length, 12, 14, 16, or 18 inches).
Boxes, junction, 3-way.
Boxes, telephone, outlet, for rifle ranges.
Boxes, telephone, portable, for rifle ranges.
Braces, cross-arm, pairs.
Brackets, iron, for lance-pole insulators.
Cable, aerial, lead-covered. (*See* table of cables.)
Cable, telephone, switchboard, 20-pair.
Clamps, strand, 2-bolt, for ¼-inch strand.
Clamps, strand, 3-bolt, for ⅜-inch strand.
Clips, cable, marline.
Clips, Crosby.
Cleats, cross-arm (wood).
Cleats, porcelain:
 2-wire.
 3-wire.
 1-wire.
 New England telephone cleat with ear.

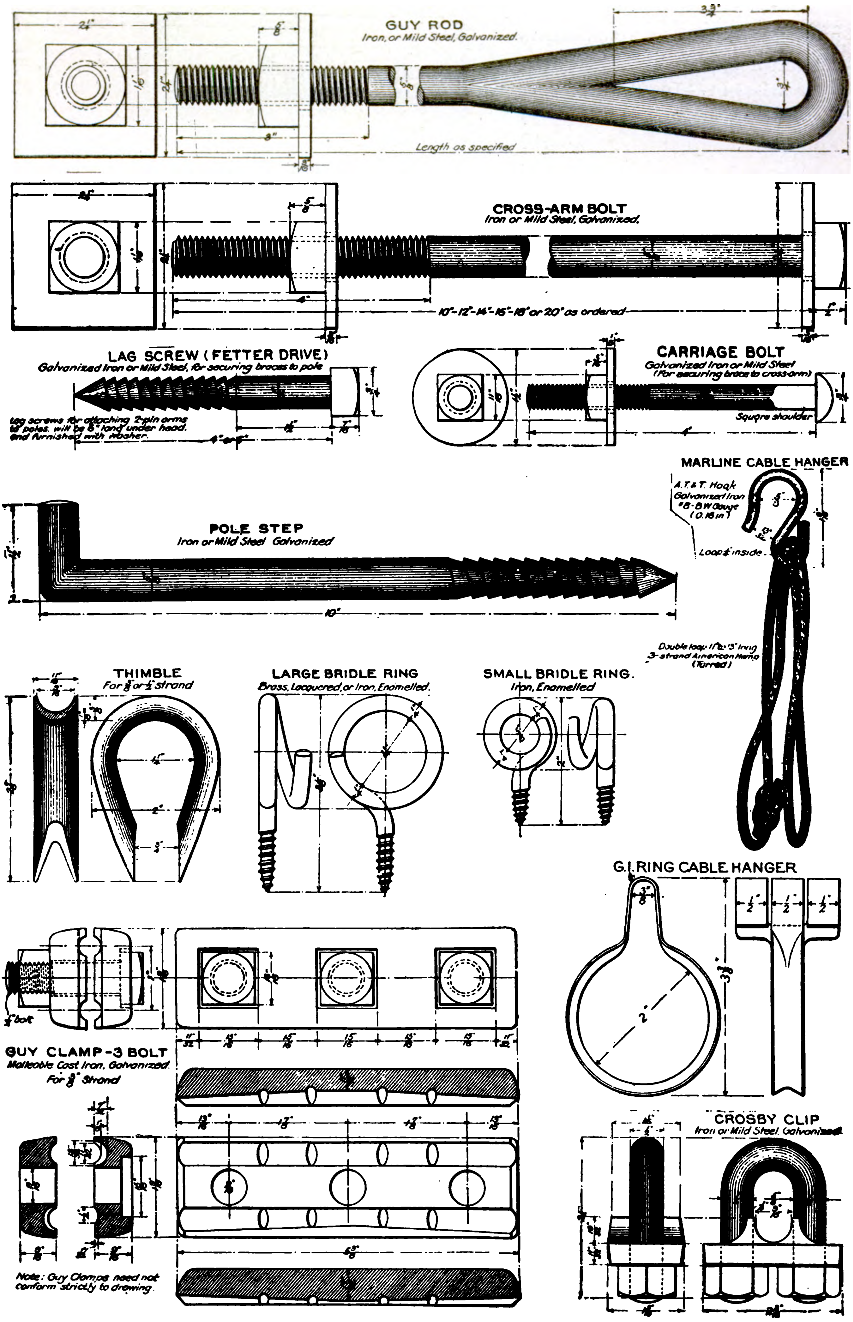


Fig. 8–12.—LINE CONSTRUCTION MATERIAL.

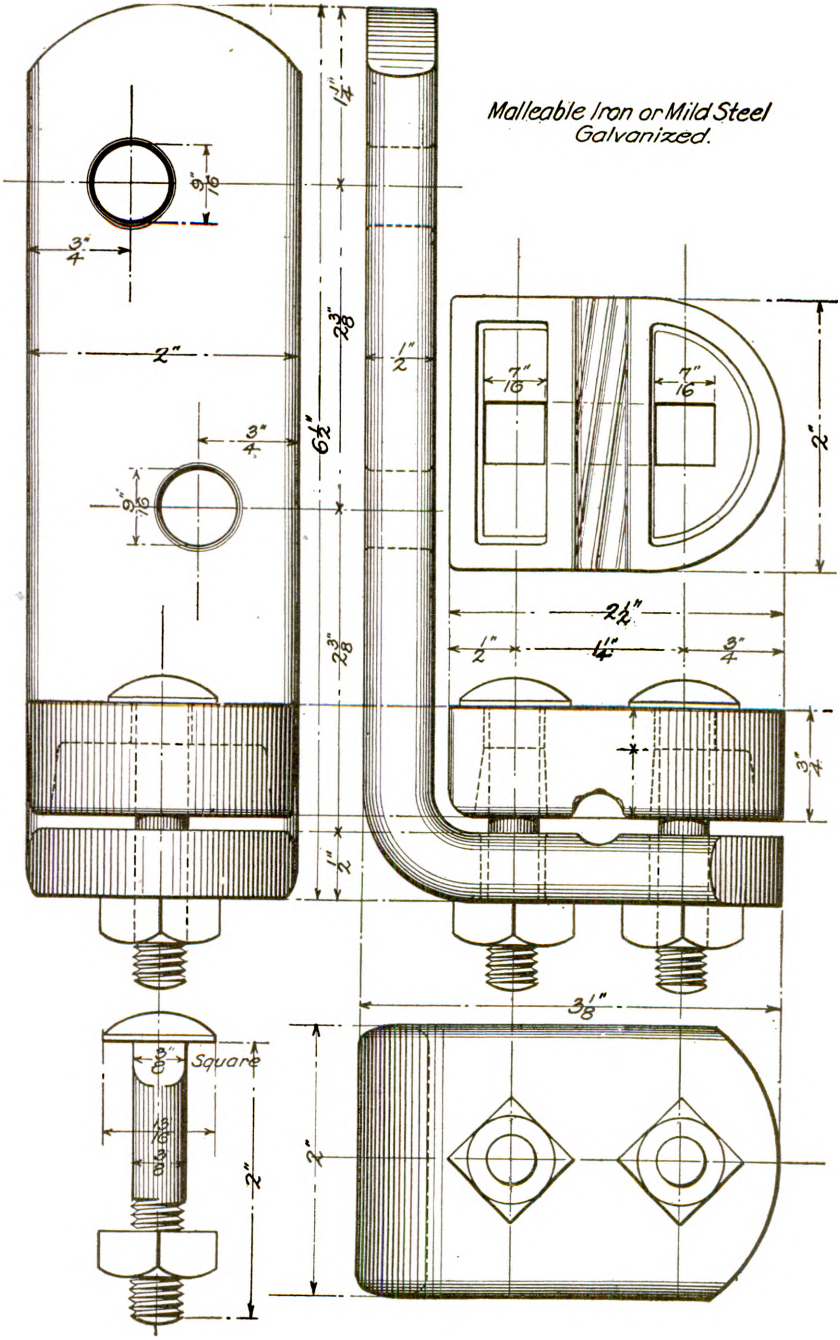


Fig. 8–13.—LINE CONSTRUCTION MATERIAL, MESSENGER SUPPORT.

Conduit, loricated or electroduct, ½ to 2 inches, with couplings and elbows.
Conduit, bituminized fiber, 3-inch.
Conduit elbows. State kind and size.
Conduit couplings. State kind and size.
Cross arms, iron pole.
Cross arms, wood (state number of pins), bored for 1½ -inch pins:
  Regular telephone size, 2¾ by 3¾ inches.
  Heavy telephone size, 3¼ by 4¼ inches.

Dimensions of standard heavy cross arms.

Length.	Number of pins.	Pin spacing.		
		Ends.	Sides.	Centers.
Feet.				
3	2	4	....	28
4	4	4	12	16
6	6	4	12	16
8	8	4	12	16
10	10	4	12	16

Forming strips.
Fuses.
Hangers, cable, marline.
Hangers, cable, Locke, 2-inch.
House line, hemp.
Insulators, pigtail, galvanized.
Insulators, pony, glass (No. 11, double groove).
Insulators, lance pole, pigtail, hard rubber or molded mica.
Insulators, lance pole, clamp, hard rubber or molded mica.
Insulators, strain, P. and S.
Insulators, porcelain, standard knobs, as follows:
  No. 4 (diameter, 1½ inches; length, 1$\frac{11}{16}$ inches).
  No. 5 (diameter, 1 inch; length, 1¼ inches).
  No. 6 (diameter, $\frac{13}{16}$ inch; length, ⅞ inch).
  No. 11 (diameter, 1⅛ inches; length, $\frac{15}{16}$ inch).
Insulators, tree, Gem or Victor.
Molding signs.
Molding, type A (two ½ by ¾ inch grooves).
Molding, type B (three ½ by ½ inch grooves).
Molding, type C (two $\frac{11}{32}$ by ½ inch grooves).
Nails, 8d, buttonhead.
Ozite.
Paint, Mogul, preservative, gallons.
Paraffin.
Pipe, iron, 2-inch, 3-inch, galvanized, per foot.
Pins, insulator, 1½-inch cross arm.
Plugs, insulator for iron poles.
Poles, steel, telegraph, 20 feet long; weight, 80 pounds.
Poles, lance, with tip, 14 feet long; weight, 8 pounds.
Poles, wooden.
Pole steps.

Desired dimensions of wood poles.

Length.	Circumference in inches—			
	For light line.		For heavy line.	
	At top.	At 6 feet from butt.	At top.	At 6 feet from butt.
Feet.				
20	16	24	16	25
25	20	30	22	32
30	20	33	22	36
35	20	36	22	40
40	20	40	22	43
45	20	43	22	47
50	20	46	22	50
55	20	49	22	53
60	20	52	22	56

Rings, bridle, ⅝-inch; 1¼-inch; 1⅝-inch; or 3-inch.
Rods, guy, ⅝ by 60 inches.
Rods, ground.
Sandpaper, standard.
Screws, state whether—
- Brass or iron.
- Machine or wood.
- Length.
- Flathead or roundhead.
- Commercial type number.

Screws, lag, state size.
Screws, lag, fetter drive.
Seats, pole.
Summary of parts:
- One angle-iron framework.
- Two braces.
- Two three-eighths (⅜) inch bolts.
- Three one-quarter (¼) inch stove bolts.
- Four one-half (½) inch lag screws.
- One wooden seat.

Sleeves, lead—order by inside diameter.
Sleeves, paper, 3/16 inch by 3 inches.
Sleeves, McIntyre—state diameter of wire in mils.
Solder, half-and-half, in bars.
Solder, plumber's wiping, in 5-pound ingots, 40 per cent tin.
Staples, d. p., "Blake," No. 3, insulated, ⅝-inch.
Strand messenger, ¼-inch to ⅝-inch.

Properties of strand.

Diameter.	Diameter of strands in mils.	Tensile strength.
Inch.		*Pounds.*
½	162	8,320
⅜	120	4,700
5/16	114	3,300
¼	72	1,750
3/16	57	1,000

Strand, guy, ¼-inch.
Supports, cross-arm (for attaching wood arms to iron poles).
Supports, messenger.
Tacks, "Milonite."
Tapes. (*See* Insulating material.)
Thimbles, guy, for ¼-inch and ⅜-inch strand.
Tags, cable.
Terminal, cable pole. (*See* Arresters.)
Tubes, porcelain:
Diameter of bore, $\frac{9}{16}$ inch; length, 1½ inches.
Diameter of bore, $\frac{11}{16}$ inch; length, 3 inches and 8 inches.

First-class wood poles should not have a sweep greater than as indicated in the following table, the sweep to be measured between the 5-foot mark and the top of the pole:

20-foot pole, sweep not more than 2 inches.
25-foot pole, sweep not more than 3 inches.
30-foot pole, sweep not more than 5 inches.
35-foot pole, sweep not more than 6 inches.
40-foot pole, sweep not more than 6 inches.
45-foot pole, sweep not more than 7 inches.
50-foot pole, sweep not more than 7 inches.

Guy stubs and anchor logs.—The timber used for guy stubs and anchor logs shall correspond in all respects with that specified for poles. Anchor logs shall not be less than 24 inches in circumference nor less than 4 feet in length.

Guy stubs shall not be less than 22 inches in circumference.

The timbers to be used for pole braces shall be of the same quality as that specified for poles. No braces shall be less than 18 inches in circumference at smaller end.

Cedar poles.

Size of pole.		Estimated weight of each.	Number of poles per carload.
Top diam.	Length.		
Inches.	*Feet.*	*Pounds.*	
4	20	100	240 to 420
5	20	130	185 to 325
6	20	175	130 to 250
7	20	210	115 to 200
4	25	150	160 to 280
5	25	200	120 to 210
5½	25	225	110 to 190
6	25	250	100 to 170
7	25	350	70 to 130
8	25	400	60 to 105
5	30	275	80 to 155
6	30	350	70 to 120
7	30	450	55 to 95
8	30	550	45 to 80
6	35	450	70 to 90
7	35	600	50 to 70
8	35	750	40 to 60
6	40	625	50 to 65
7	40	800	40 to 55
8	40	975	30 to 45

Cedar poles.

Size of pole.		Estimated weight of each.	Number of poles per load (2 cars).
Top diam.	Length.		
Inches.	*Feet.*	*Pounds.*	
7	45	1,000	60 to 70
8	45	1,150	52 to 58
7	50	1,250	48 to 55
8	50	1,350	44 to 48
7	55	1,550	39 to 42
8	55	1,750	34 to 37
7	60	2,000	30 to 33
7	65	2,700	23 to 25

MARKING HAMMERS.

Whenever inspections of considerable quantities of poles, wooden conduits, cross arms, or other rough woodwork are required, the inspector will be supplied with a marking hammer showing the crossed flags of the Signal Corps and a letter indicating the office from which the inspection was made.

These marking hammers will be supplied by Department Signal Officer or signal office, Washington, when needed.

LINE CONSTRUCTION TOOLS.

[Standard construction tools as described in specification No. 360.]

Adz, house carpenter's full head, 4-inch blade, Fayette R. Plumb's or American Axe & Tool Co.

Ax, hand (specified as broad hatchets), 5-inch blade, Plumb's, Germantown, or Keen Kutter.

Axes, handles for, to be hickory, clear, straight-grained.

Ax, lineman's 5-pound, long-handle, all steel, Plumb's, Germantown, or Keen Kutter.

Bags, lineman's best canvas, with leather bottom, 20-inch, letters "U. S. S. C.," 1 inch high, in indelible ink stenciled thereon, W. E. No. 15201.

Bars:

Crow, wedge point, 17 pounds, best tool steel.

Digging, 1 inch round, 8 feet long, weight 17 pounds, and 1¼ inches round, 8 feet long, weight 28 pounds; both to be of solid steel.

Digging and tamping, 1 inch round tool steel, 7 feet long, weight 19 pounds; 1 inch octagonal tool steel, 8 feet long, weight 25 pounds.

Digging (electric spud), steel tubing, with cast blade and tamper.

Belts, lineman's, for tools, with loops, rings, and safety strap, as per drawing, paragraph 3 (*b*).

Bits:

Auger, Irwin, sizes ¼-inch, 5/16-inch, ⅜-inch, ½-inch, ⅝-inch, ¾-inch, all 8 inches long.

Expansion, ⅞ inch to 3 inches, C. E. Jennings's.

Pole, Irwin, 12 inches by ⅝ inch, and 16 inches by ⅝ inch.

Blades, hack-saw, 10-inch, Milford.

Blocks:

Pulley, Star brand, Boston & Lockport Block Co., galvanized malleable iron, as follows (all blocks with one hook and one becket): Single or double, 3-inch block for ⅜-inch rope, 1¾-inch sheave; double or triple, 6-inch block for ¾-inch rope, 3½-inch sheave; double or triple, 10-inch block, 6¼-inch sheave.

Roller for cable.

Braces, ratchet, 8-inch sweep, Millers Falls Co. or Barber's Improved.

Buffalo grip with pulleys No. 1 size, W. E. Co., for wires up to No. 162 mils diameter.

Chain, cow, 4 feet, with rings.

Chisels, cold, ¾-inch to 1-inch, tool steel.

Chisels:

Socket-framing, 1½ inches to 2 inches.

Socket-framing, handles for, ring-topped, best quality hickory.

Clamps, combination splicing, for wires 64 to 204 mils diameter, iron; for 64 to 128 mils diameter, copper (for McIntyre connecters).

Climbers:

Klein's Eastern, 16 inches and 18 inches, with straps and pads.

Straps and pads, for Klein's Eastern, to be of best quality leather.

Coppers:

Soldering, with handles, 1 pound, 2 pounds, and 4 pounds.

Soldering, handles for, with ring ferrules.

Cord, Sampson spot, waterproof, three-eighths (⅜) inch diameter, in coils of 100 feet.

Drill, rock, made of best tool steel, large and small sizes.

Files:

Nicholson or Disston; dentist file; 5-inch triangular; 8-inch round; flat; bastard; half-round; 8-inch.

Handles for, wood.

Frames, hack-saw, Star No. 10.

Furnace, gasoline, with 6-inch pot and 3-inch ladle, Whilte's or Clayton & Lambert's No. 10, galvanized tank.

Globes, plain or ruby.

Hammers:

Claw, 18-ounce, Maydole, Atha, or Keen Kutter.

Machinists, 2-pound, Maydole, Atha, or Keen Kutter.

And hatchets, handles for, best grade hickory.

Handles with tools, No. 5, Millers Falls Co.

Hooks:

Cant, 4-foot, with handle, Dickie Tool Co.

Carrying, 4-foot handle, Dickie Tool Co.

Jack strap, complete, with hook and No. 1 Buffalo grip, W. E. Catalogue, No. 2667.

Kit, tool, inspector's pocket.

Knives:

Draw, telegraph pattern, 12-inch and 14-inch blade, Jennings'.

Electrician's, Empire Knife Co., No. 1013.

Lanterns, excavation, ruby globe, Dietz, or Ham's tubular.

Pick handles, straight-grained hickory, 36 inches long.

Picks, Iron City or Klein & Logan's, 7 pounds to 8 pounds.

Pike, guarded or raising, 14-foot.

Pliers:

Lineman's, 6-inch side cutting, U. D. F. & T. Co., No. 50, or P. S. & W., No. 40.

Lineman's, 8-inch side cutting, U. D. F. & T. Co., No. 50, or P. S. & W., No. 40.

6-inch diagonal, F. Linstrom.

Poles, pike, 12-foot, 16-foot, and 18-foot, 2 inches in diameter, straight live ash, or white or yellow pine to suit locality.

Pole support:

Jenny, 7-foot.

Mule, 6-foot.

Post-hole augers, 12-inch, 5 feet long, Hercules.

Post-hole diggers, 6-foot or 7-foot handles.

Reels:

Pay-out, with or without shoulder straps, as ordered.

Take-up.

Reel jacks:

Klein's or King's, for 2¼-inch shaft, capacity 10 tons per pair.

Axes for, steel, 1-inch, 1½-inch, 2-inch, and 2½-inch.

Rope, pure manila hemp:

⅜-inch, in coils of 1,000 feet.

½-inch, in coils of 1,000 feet.

⅝-inch, in coils of 500 feet.

¾-inch, in coils of 500 feet.

1-inch, in coils of 500 feet.

Rules:

2-foot, folding, boxwood, brass bound, No. 62½, C. S. Co.

Zigzag, 4-foot, Stanley Rule & Level Co.

Saws:

Crosscut, Disston's, 5-foot, with handles.

Hand, 26-inch, No. 7, 8-point, Disston's.

Rip, 26-inch, 5½-point, Disston's.

Screw drivers, Perfect, 3 inches, 4 inches, 6 inches, and 12 inches.

Shovels:

6-foot and 8-foot handles, with 18-inch straps, Ames's or Griffith's.

Handles for.

Spades:

Grading, round and square pointed, D handles.

Handles for.

Spoons, 6-foot and 8-foot handles, 18-inch strap, Ames's or Griffith's.

Straps, safety, for lineman's belts.

Tape line, metallic, Lufkin, 100 feet and 50 feet, in feet and inches, leather case.

Torches, blow, hot blast, Clayton & Lambert's, No. 32.

Tree trimmers:

Large size, without saws.

Large size, with saws.

Handles for, 18 feet, with ferrule joint.

Wrench, combination lag screw and nut, Klein's.

Wrenches, monkey, Coe's, 10-inch and 12-inch, or P. S. & W., No. 100.

Following is a brief description and enumeration of contents of the various instrument and tool kits which have been devised by the Signal Corps for issue to construction parties, inspectors and for use in maintenance of electrical systems. It is specified that all tools furnished shall be of the best of their kind and type.

ELECTRICAL INSTRUMENT CASE.

[This electrical case is manufactured under specification No. 145.]

The electrical instrument case is issued wherever an extensive cable system is installed or whenever exhaustive and accurate tests of cable are desired. The case is of oak, reinforced at corners with metal. Figure 8–14 illustrates this case. For description and use of instruments contained in the electrical instrument case, see chapter 4 of this Manual.

CONTENTS.

1 insulation and capacity test set, consisting of the following:
- 1 portable galvanometer of the D'Arsonval type, conforming to drawing No. 178*b*.
- 1 telescope and scale for above galvanometer.
- 1 100,000-ohm box.
- 1 combined shunt and switch.
- 1 condenser set.
- 1 ohmmeter.
- 1 tripod (external to case).
- 1 service testing battery, drawing No. 199, specification No. 185.
- 1 micrometer caliper, B. & S., No. 8, without ratchet stop, with morocco-carrying case.
- 1 inspector's pocket tool kit, as per drawing No. 204, specification No. 186.
- 1 testing telephone, to be furnished by the United States Signal Corps, space to be provided by the contractor, as per drawing.
- 1 space for forms and reports.
- 1 space for books.

MISCELLANEOUS PARTS AND SUPPLIES.

1 galvanometer coil and mirror.
4 round-head plugs.
6 lower suspensions.
6 upper suspensions.
2 milled-head screws.
1 piece felt.
4 screws for glass.
1 ohmmeter card.
1 piece chamois.
1 bottle vaseline.
1 bottle typewriter oil.
100 feet No. 22 bare copper wire.
100 feet advance wire, No. 28.
25 feet No. 22 manganin wire.
150 feet No. 34 manganin wire.
300 feet No. 40 manganin wire.
60 feet No. 28 manganin wire.
1 glass window.
4 paper scales.
6 feet battery cord.
10 feet okonite wire.
8 ounces solder.

REPAIR KIT.

The repair kit contains the following instruments:

1 nickel-plated screw driver.
2 pairs tweezers, nickeled.
3 lower suspensions for galvanometer.
4 upper suspsnions for galvanometer.

MECHANICS' TOOL CHESTS.

[These chests are manufactured under specification No. 562.]

Mechanics' tool chests are for issue to Signal Corps field companies for use in connection with the repair of apparatus. There are two chests, differing slightly in dimensions and equipment, and are designated "Mechanic's tool chest No. 1" and "Mechanic's tool chest No. 2." They are constructed of heavy, straight-grained oak, substantially reinforced at corners with metal corner braces.

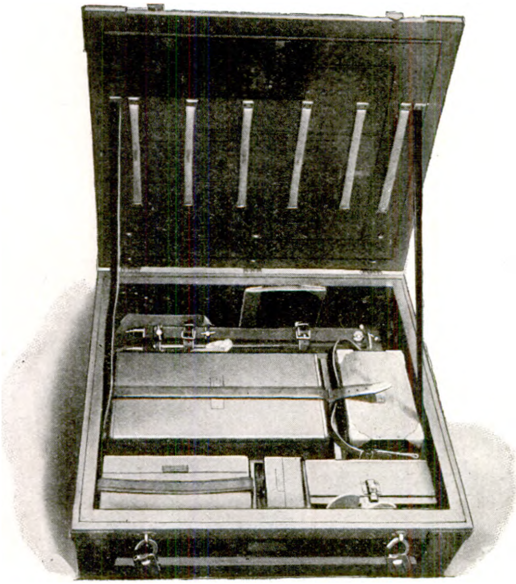


Fig. 8-14.—CASE, ELECTRICAL INSTRUMENT.

Name plate.

For Chest No. 1—

MECHANIC'S TOOL CHEST,
NUMBER ONE,
FIELD COMPANY,
SIGNAL CORPS, U. S. ARMY.
Serial No. ——.

For Chest No. 2—

MECHANIC'S TOOL CHEST,
NUMBER TWO,
FIELD COMPANY,
SIGNAL CORPS, U. S. ARMY.
Serial No. ——.

The chests are fitted with Corbin padlock No. 2882, or equal, no two of which have keys alike, except the two locks for No. 2 chest, which shall be opened by the same key. A duplicate set of keys is furnished for each lock.

With the exception of items marked (*) each tool is stamped with the number assigned to it in the following list.

The chests are equipped and tools distributed as follows:

CHEST No. 1.

Lid.

1. 1 frame, hack-saw, Star, No. 10.

Top of chest.

2. 1 pliers, side-cutting, 6 inches, U. D. F. & T. Co., No. 50, or P. S. & W., No. 40.
3. 1 pliers, diagonal, 6 inches, F. Linstrom, No. 842.
4. 1 pliers, long-nose, 5½ inches, U. D. F. & T. Co., No. 654.
5. 1 shears, metal, W. H. Compton, "Reliance," No. 10.
6. 1 hammer, riveting, 4 ounces, Maydole, cast steel.
7. 1 oil can, bicycle or pocket type, 2½ inches diameter, ¾-inch thick, curved, spout with screw cap.
8. 1 drill, hand, Goodell Pratt Co., No. 5½.
9. 1 vise, adjustable jaw, swivel base, 2-inch jaws, No. 37, Prentiss.
10. 1 screw-driver set, Yankee, No. 100.

*11. 1 drills, twist, set of 60, straight shank, Morse, Nos. 1 to 60.

Fig. 8–15.—CHEST, TOOL, MECHANICS NO. 2.

End of chest.

12. 1 torch, gasolene, Clayton & Lambert, No. 32.
13. 1 grinder, hand, with 1 by 5 inch Norton grinding wheel, American, No. 2.

Drawer No. 1.

14. 1 screw-plate set, Little Giant, No. A A 4.
15. 1 square, combination, 6-inch blade without center head, Athol, No. 4.
16. 1 oilstone, mounted, 8-inch soft, Arkansas, Pike's.
17. 1 screw driver, machinist's, swivel head, 5 inches, $\frac{5}{32}$-inch blade, $\frac{5}{16}$-inch handle, Syracuse.
18. 1 chisel, cold, ½-inch, 6 inches long, "Diamond edge."
19. 2 center punches, straight-shank, Syracuse, No. 16.

*20. 4 files, 4-inch, round.

*21. 4 files, 4-inch, square.

*22. 6 files, 6-inch, round.

23. 1 handle, file, malleable iron, I. X. L.
24. 1 iron, soldering, ½ pound.
25. 1 iron, soldering, 1½ pounds.

Drawer No. 2.

26. 6 files, 8-inch, flat, bastard, "Arcade U. S. A."
27. 1 file cleaner, Colton's No. 10 or similar.
*28. 2 hack-saw blades, dozen, 12 inches, Disston's.

CHEST No. 2.

Cover.

1. 1 saw, hand, 10-point, Disston's, 26-inch.
2. 1 saw, rip, 6-point, Disston's, 28-inch.
3. 1 square, 24-inch, Russell & Erwin, No. 14 (short end cut to 14 inches).
4. 1 rule, Stanley, No. 104.

Top of chest.

5. 1 wrench, monkey, 15-inch, P. S. & W.
6. 1 wrench, monkey, 6-inch, P. S. & W.
7. 1 wrench, Stillson, 14-inch.
8. 1 screw driver, 7-inch, "Champion."
9. 1 screw driver, 5-inch, "Champion."
10. 1 nail puller, "Little Giant."
11. 1 knife, draw, 8-inch, A. J. Wilkinson & Co., Boston, folding type.
12. 1 hammer, riveting, 8-ounce, Maydole, cast steel.
13. 1 hammer, claw, Maydole, 11½.
14. 1 tape, steel, 100-foot, Lufkin's "The Rival."
15. 1 brace, 10-inch, Millers Falls Co.
16. 1 chisel, set of 5, 1¾, 1¼, ⅞, ⅝, and ¼ inches, Jennings's No. 70.
17. 1 calipers, pair, 4-inch.
18. 1 dividers, pair, 6-inch, P. S. & W., wing or equal.

Lower drawer.

19. 1 screw plate, set, Conant & Donaldson Co.'s "Reliable," No. 35.
20. 1 plane, jack, 2-inch bit, Stanley.
21. 1 plane, block, 1⅝-inch bit, Stanley.
22. 1 oilstone, Pike, soft Arkansas, 5-inch, mounted.
23. 1 saw, set, Morrill's, No. 11.

Upper drawer.

24. 1 file holder, I. X. L., malleable iron.
25. 1 file cleaner, Colton's No. 10, or similar, metal back.
*26. 1 drill, twist, bit stock, set of 9, 3 each of $\frac{5}{16}$, $\frac{7}{16}$, and ½ inch diameter.
*27. 1 files, set of 14, Nicholson, three 8-inch, half-round, smooth; three 8-inch, half-round bastard; two 8-inch, flat bastard; six 6-inch saw files.
*28. 1 bits, set of 14; 13 Irwin's ¼-inch to 1-inch by $\frac{1}{16}$-inch, and 1 bit, C. E. Jennings's expansive, ⅞ to 3 inches.

The last three items will be incased in canvas rolls. These canvas rolls are to be neatly and strongly made of 10-ounce khaki canvas, leather bound, with flap and 1-inch strap and buckle. The roll for the twist drills shall be 19 inches long when opened out. The roll for the files shall be 27 inches long when opened out. The roll for the bits shall be 36 inches long and shall have a small leather pocket securely sewed on the inside for the extra cutters of the expansive bit.

29. 1 hatchet, half, with handle, Germantown No. 2, thin blade.

AEROPLANE TOOL CHEST.

[These chests are manufactured under specification No. 562.]

The aeroplane tool chest is for issue to aeronautical companies or detachments detailed in connection with aeronautical work. The chests are identical with mechanic's tool chest No. 2, except that certain partitions are omitted.

Name plate.

AEROPLANE TOOL CHEST.

SIGNAL CORPS, U. S. ARMY.

Serial No. ——.

CONTENTS.

Cover.

1. 1 saw, hand, 10-point, Disston's, 26-inch.
2. 1 hammer, riveting, 8-ounce, Maydole.
3. 1 combination square, bevel and level, 12-inch, Athol.
4. 1 rule, Stanley, No. 104.
5. 1 hack saw frame, Millers Falls Co., No. 6.
6. 1 dividers, pair, 6-inch, P. S. & W.

Top of Chest.

7. 1 wrench, Stillson, 14-inch.
8. 1 screw driver, 7-inch, Perfect.
9. 1 screw driver, 5-inch, Perfect.
10. 1 nail puller, Little Giant.
11. 1 knife, draw, 8-inch, A. J. Wilkinson & Co., Boston, folding type.
12. 1 hammer, tinsmith, 1-pound, Atha.
13. 1 hammer, claw, Maydole.
14. 1 tape, 100-foot, steel, Lufkins "The Rival."
15. 1 brace, 10-inch, Millers Falls Co., No. 32.
16. 1 iron, soldering, 1½-pounds; 1 iron, soldering, jeweler's, No. 1; 2 center punches, 4-inch, Syracuse; 24 blades, hack saw, 10-inch, coarse, Star; 12 blades, hack saw, 10-inch, Star, No. 20; 1 chisel, cold, ¾-inch, Village Blacksmith; 1 chisel, cold, ½-inch, Village Blacksmith.
17. 1 screw driver, 8-inch, Perfect.
18. 1 calipers, double, 6-inch, Starrett, No. 44.
19. 1 wrench, monkey, 6-inch, P. S. & W.

Upper Drawer.

20. 1 bit, C. E. Jenning's expansive, ⅞ inch to 3 inch, with leather pocket for cutter.
21. 1 pliers, round nose, 6-inch, Bernard.
22. 1 pliers, snipe nose, 4-inch, Bernard.

23. 1 pliers, adjustable, 8-inch, Danielson.
24. 1 pliers, side cutting, 8-inch, Utica, No. 50.
25. 1 pliers, adjustable, 6-inch, Danielson.
26. 1 pliers, Auto, 6-inch, combination, cutting, Kraeuter & Co.
27. 1 pliers, Auto, 8-inch, combination, cutting, Kraeuter & Co.
28. 1 nipper-cut, No. 1, Starrett, 7-inch M.
29. 1 pliers, 6-inch, diagonal, No. 842, Linstrom.
30. 1 pliers, 6-inch, diagonal, No. 842, Linstrom.
31. 1 pliers, compound, 8-inch, side cutting, No. 502, Vulcan.
32. 1 file holder, I. X. L.
33. 1 pliers, 8-inch, adjustable, Danielson.
34. 1 spoke shave, 3-inch, No. 80, Sargent; and 1 file cleaner, Colton's No. 10.
35. 2 files, smooth, 8-inch, half-round; 1 file, bastard, 8-inch, half-round; 2 files, bastard, 8-inch, flat; 2 files, saw, 6-inch; 1 file, bastard, 10-inch; 1 file, round, 6-inch; 1 file, bastard, 8-inch, square (all Nicholson files); to be contained in a roll 27 inches long and 13½ inches wide, consisting of 10 pockets 7 inches deep with a flap 9 inches wide and 20 inches long, pockets extending over 20 inches to take the files specified. This roll and the rolls for items 42 and 43 shall be made of 10-ounce cotton duck, khaki shade, all edges leather bound, to be fastened with strap and buckle.
36. 1 screw driver, 4-inch, Perfect.
37. 1 wrench, bicycle, 5-inch, Billings & Spencer.
38. 1 wrench, bicycle, 5-inch, Billings & Spencer.
39. 1 palm, sewing; two 4-inch sailmaker's needles; six 4-inch, one-quarter curve, needles; 1 ball Irish flax, Barbour's No. 3, 2-ounce; 1 ball wax.

Lower drawer.

40. 1 stone, 5-inch Carborundum, combination, No. 111, in wood case.
41. 1 torch, gasoline, flat, Clayton Lambert No. 48 (fastened by strap with buckle).
42. 1 set thin open-end wrenches, set of 4 Ronson ¼ to $\frac{25}{32}$ and 1 J. P. Williams No. 30, to be contained in a roll 27 inches by 11 inches, consisting of eight pockets 4½ inches deep, extending over 20 inches to take the wrenches specified, with a flap to cover the pockets 20 inches by 9 inches, the material to be as described in item 35.
43. 1 set drills, Morse, straight shank, Nos. 1 to 45, inclusive; 1 drill, ⅜-inch; 1 drill, ¼-inch; and 1 drill, $\frac{5}{16}$-inch; to be contained in a roll 27 inches by 8 inches, consisting of 11 pockets to take large drills, extending over 15 inches, with a flap 21 inches with a piece on under side for pockets to take drills Nos. 1 to 45, the material to be as described in item 35.
44. 1 plane, block, 1⅝-inch, Stanley No. 110.
45. 1 drill, hand, Yankee No. 1545.
46. 1 wrench, 7-inch, Billings & Spencer.
47. 3 reamers, taper, bit stock, Wiley Russell "Lightning," one ¼-inch; one $\frac{5}{16}$-inch; one ⅜-inch.
48. 1 hatchet, half, No. 2, thin blade, Germantown No. 316.
49. 1 snips, tinner's, Reliance No. 10.

The following list enumerates the tool kits furnished by the Signal Corps for use in the installation of fire control, telephone, and small-arms signaling systems, or for any construction work where its magnitude warrants such an issue. When used for such purposes they should invariably be returned to a

Signal Corps supply depot when they have served the purpose, unless specific authority for their retention has been issued. Some of these kits are also issued for use in connection with maintenance of systems:

Electrical engineer's tool chest.
Construction tool chest.
Cable splicer's chest.
Pipe fitter's chest.
Post tool chest.
Service tool bag.
Inspector's pocket kit.

The electrical engineer's, construction, and post tool chests are constructed of the best selected oak or ash lumber, thoroughly seasoned. The ends and sides of these chests are joined by dovetailed joints, and the chests are fitted with steel or malleable-iron corner irons, wrought-iron hinges, heavy brass hasps, and heavy brass drop handles.

The cable splicer's and pipe fitter's tool chests are constructed of sheet steel, reinforced with hardwood strips and malleable-iron fittings.

ELECTRICAL ENGINEER'S TOOL CHEST.

[This chest is manufactured under specifications No. 192]

This chest, shown in figure 8–16, is issued to electrical experts of the Signal Corps, or to any person in responsible charge of fire-control or post-telephone construction work.

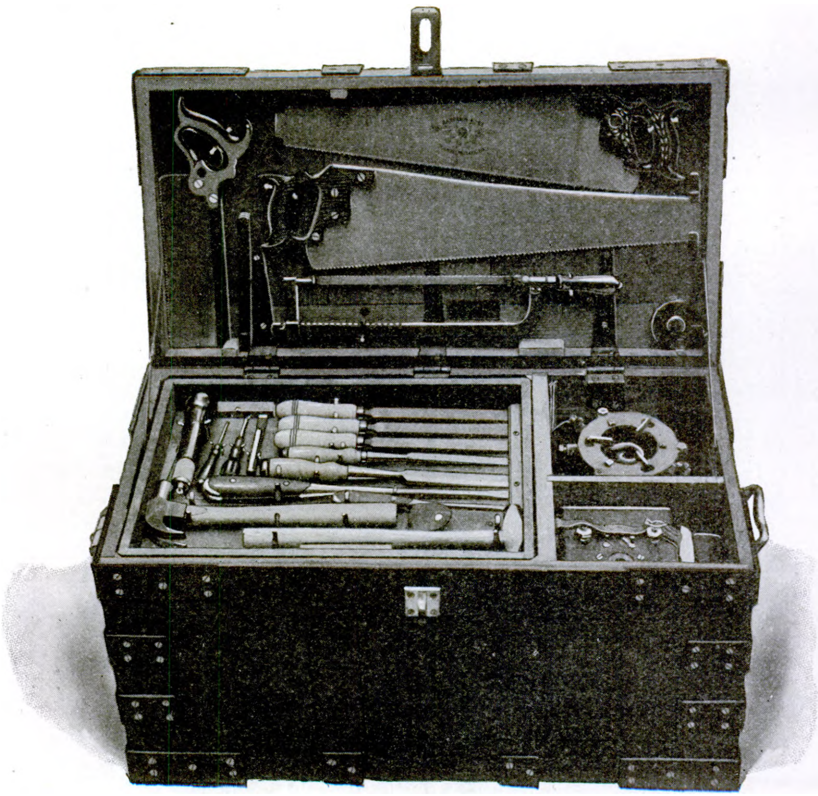


Fig. 8–16.—CHEST, TOOL, ELECTRICAL ENGINEERS.

Upon approval of the Chief Signal Officer of the Army this chest is also issued to coast defense Artillery Engineers of large coast-defense commands for use in maintaining the fire-control and post-telephone systems.

The chest contains a full complement of tools necessary for the installation of apparatus.

Name plate.

ELECTRICAL ENGINEER'S TOOL CHEST.

U. S. SIGNAL CORPS.

No. ——.

The tools are distributed as follows:

Cover.

1. 1 backsaw, 10 inches, No. 1, Disston's.
2. 1 rule, 4-foot, 8-fold, Stanley, No. 404.
3. 1 crosscut saw, 20 inches, 9 teeth per inch, Disston, No. 7.
4. 1 ripsaw, 22 inches, 6 teeth per inch, Disston, No. 7.
5. 1 hack-saw frame, Star, No. 10.
6. 1 tape, metallic, 50 feet, Lufkin Rule Co., No. 503.

First tray.

7. 1 spirit level, pocket, 3-inch, No. 31, Stanley's.
8. 1 polarity indicator, Manhattan, M. E. S. Co., No. 3321.
9. 1 wrench, Athol Manufacturing Co., "Rapid Transit," 6 inches, black, No. 541.
10. 1 hammer, riveting, 15 ounces, "Atha," No. 234.
11. 1 hammer, claw, 1 pound, "Atha," No. 41½.
12. 1 jackknife, "Empire," Winsted, Conn., No. 1013.
13. 1 screw driver, 5 inches, "Perfect."
14. 1 screw driver, 10 inches, "Perfect."
15. 1 chisel, socket, 1-inch, "Jennings," No. 70.
16. 1 chisel, socket, ½-inch, "Jennings," No. 70.
17. 3 files; two 8-inch flat bastard, one 8-inch clear edge, hand, bastard, "Arcade, U. S. A."
18. 1 chisel, cold, ½-inch, 6 inches long.
19. 1 screw driver, 2 inches, Tucks Giant.
20. 1 screw driver, 2½ inches, No. 825, O. W. Bullock & Co.
21. 1 tool holder with tools, Millers Falls Co., No. 5.

Second tray.

22. 1 dividers, pair, 6-inch, P. S. & W. wing, or equal.
23. 1 ratchet brace, Millers Falls Co., 8-inch throw, No. 33.
24. 2 buffalo grips, with pulleys, one each, Nos. 1 and 2, W. E. Co.
25. 1 scale, 12-inch, combination square (Athol), No. 500, 12-inch set, complete.
26. 1 center head, combination square (Athol), No. 500, 12-inch set, complete.
27. 1 square and bevel, combination square (Athol), No. 500, 12-inch set, complete.
28. 1 vise, hand (Athol), No. 549, 1½ inches.
29. 1 plane, block, Stanley, No. 130.

30. 1 shears, pair, metal, W. H. Compton "Reliance," No. 10.
31. 1 soldering copper, jeweler's, No. 2.
32. 1 soldering copper, 1 pound.
33. 1 soldering iron, electric, No. 10, American Electric Heater Co., with Edison attachment plug.

Third tray.

34. 1 oilstone, "Pike," soft Arkansas, 5-inch, mounted.
35. 1 pliers, pair, 8-inch, side-cutting, U. D. F. & T. Co. No. 50, or P. S. & W. No. 40.
36. 1 ladle, 3-inch, wrought-iron handle.
37. 1 pliers, pair, $5\frac{1}{2}$-inch, long nose, side-cutting, U. D. F. & T. Co. No. 354.
38. 1 monkey wrench, Coe's 12-inch, or Bemis & Call's No. 54, or P. S. & W. No. 100.
39. 1 nail puller, Little Giant.
40. 1 wrench, Stillson, 14-inch.
41. 1 pliers, pair, 6-inch, side-cutting, U. D. F. & T. Co. No. 50, or P. S. & W. No. 40.
42. 1 pliers, pair, diagonal cutting, 6-inch, No. 842, F. Linstrom.
43. 2 clamps, combination splicing, Klein, No. 309.

Fourth tray.

44. 1 countersink, wood, C. E. Jennings, No. 001.
45. 9 drills, steel twist, $\frac{1}{2}$-inch, $\frac{7}{16}$-inch, $\frac{3}{8}$-inch, $\frac{5}{16}$-inch, $\frac{1}{4}$-inch; Nos. 2, 12, 22, and 30, and 1 center punch, No. 16 Syracuse; straight shank, standard.
46. 1 punches, set, alphabet, $\frac{1}{8}$-inch.
47. 1 plumber's kettle, 5 inches.
48. 1 drill, breast, Millers Falls, No. 18.
49. 2 shields for fire pot.
50. 1 figures, set, steel, $\frac{1}{8}$-inch.
51. 1 bit, expansion, 2 cutters, $\frac{7}{8}$-inch to 3 inches, Clarke's.
52. 1 plane, rabbet, $\frac{1}{2}$-inch.
53. 1 knife, cable sheath, $4\frac{1}{2}$-inch blade, "Village Blacksmith," Milwaukee.
54. 1 bits, set of Irwin auger, with 4-inch triangular file, $\frac{3}{16}$-inch to 1-inch by sixteenths.

End of chest.

55. 1 furnace, Clayton & Lambert's, No. 10, galvanized tank.
56. 1 lineman's magneto testing set (furnished by U. S. Signal Corps).
57. 1 hack-saw blades, dozen, all hard, 10 inches, Milford.

CONSTRUCTION TOOL CHEST.

[This chest is manufactured under specification No. 400.]

The construction tool chest, figure 8–17, is issued to any person in responsible charge of fire-control or post-telephone construction work, and upon approval of the Chief Signal Officer of the Army is issued for use in connection with maintenance.

While this chest is larger in size than the electrical engineer's tool chest, it does not contain so great an assortment of tools.

It is particularly adapted for use where construction or maintenance of aerial lines is concerned.

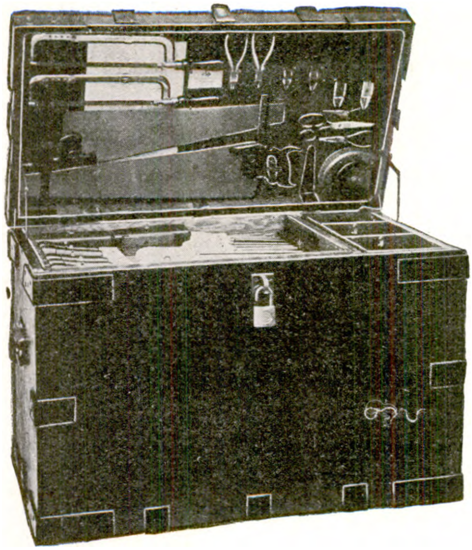


Fig. 8–17.—CHEST, TOOL, CONSTRUCTION.

Name plate.

CONSTRUCTION TOOL CHEST.

U. S. SIGNAL CORPS.

No. ——.

This chest shall be provided with Corbin lock No. 2882, or equal, and duplicate set of keys.

2 axes, hand, 4½ inches, Germantown.
1 bag, tool, service, empty.
1 bit, bellhanger's, 24 by ⅜ inches, Syracuse, style E.
2 bits, sets, Irwin, in boxes (25½), quarters.
3 blades, hack saw, 10-inch, Milford, dozen.
1 box, miter, Perfection.
2 braces, Millers Falls, No. 33.
2 chisels, wood, 1-inch, Jennings, No. 70, socket.
2 coppers, soldering, with handles, 2½ pounds.
1 copper, soldering, with handle, jeweler's, No. 1.
1 dies, marking, steel, figures, ¼-inch, hand cut, set.
1 dies, marking, steel, letters, ¼-inch, hand cut, set.
1 drill, breast, Millers Falls, size No. 18.
12 drills, rock, 5/16-inch, Star.
12 drills, rock, 9/16-inch, Star.
7 drills, twist, straight shank, ⅛ to ½ inch in sixteenths, standard.
8 files, assorted, with handles; 2 bastard, half-round, 10-inch; 2 hand, safe edge, 6-inch; 2 slim taper saw files, 5½-inch; 1 round file, 6-inch; 1 rasp, cabinet, 10-inch, Genuine McCaffrey; 2 frames, hack saw, Star, No. 10.
2 gouges, ¾-inch, Jennings, No. 91, socket.
2 grips, buffalo, one each Nos. 1 and 2, W. E. Co., with pulleys.

6 hammers, claw, carpenter's, 15-ounce, No. 41½, Atha.
6 holders, tool, with tools, Millers Falls Co., No. 5.
1 indicator, polarity, M. E. S. Co., No. 3321.
2 kits, tool, inspector's pocket.
1 knife, cable, sheath, 4½-inch blade, "Village Blacksmith," Milwaukee.
6 knives, Empire, No. 1013.
1 mallet, serving, metal.
1 mallet, wooden.
1 oilstone, Pike, soft, Arkansas, 5-inch, mounted.
1 plane, block, 1½-inch blade, Stanley, No. 220.
1 plane, fore, 2½-inch blade, Union Manufacturing Co.'s No. 28.
1 plane, jack, 2-inch blade, Union Manufacturing Co.'s No. 26.
1 plane, rabbet, ½-inch blade, Union Manufacturing Co.'s No. 157.
2 pliers, diagonal, cutting, 6-inch, pairs, F. Linstrom, No. 842.
1 pliers, gas, 8-inch, P. S. & W., pair.
2 pliers, side-cutting, 6-inch, U. D. F. & T. Co. No. 50, or P. S. & W. No. 40.
2 pliers, side-cutting, 8-inch, U. D. F. & T. Co. No. 50, or P. S. & W. No. 40.
2 pliers, long-nose, 5½-inch, U. D. F. & T. Co. No. 654, pairs.
1 punch, center, Syracuse, No. 16.
2 saws, back, 10-inch, Disston's.
1 saw, compass, 12-inch, Disston's.
1 saw, crosscut, carpenter's, 20-inch, Disston's, 9 points, No. 7.
1 saw, rip, carpenter's, 22-inch, Disston's, 6 points, No. 7.
2 screw drivers, 12-inch, Perfect.
1 shears, 8-inch, pair, straight trimmers, Compton.
1 snips, pair, No. 10, Compton.
1 tape, 50-foot, metallic, Lufkin, No. 503.
2 torches, gasoline, Clayton & Lambert, No. 32.
1 try-square, steel, 6-inch, Stanley, No. 12.
1 wrench, screw, 12-inch, Coe's or Bemis & Call's, No. 54.
1 wrench, Stillson, 14-inch.

CABLE SPLICER'S CHEST.

[This chest is manufactured under specification No. 318.]

This chest, shown in figure 8–18, includes all tools necessary for the splicing of cable, together with one-quarter pound stearine, 1 pound of gummed paper, 250 paper sleeves three-sixteenths inch by 3 inches, and two cotton strips one-fourth inch, in rolls 5 inches in diameter. Dependence can not be placed in the chest containing the expendable articles listed above unless it is supplied directly from a Signal Corps supply depot.

Name plate.

CABLE SPLICER'S CHEST,

U. S. SIGNAL CORPS.

No. ——.

Equipment.

1 plumber's furnace, with two chimneys, No. 10 C. & L. Mfg. Co. (galvanized tank).
1 ladle, 3 inches, W. I., with wrought-iron handle.
1 inspector's pocket kit.

Fig. 8–18.—CHEST, TOOL, CABLE SPLICERS.

1 hook shave, No. 949, oval, A. S. Morse Co.
1 plumber's kettle, 5 inches.
2 soldering coppers, 2½ and 4 pounds, with handles.
1 knife, cable, sheath, 4½-inch blade, "Village Blacksmith," Milwaukee.
1 saw, plumber's, Disston's, 14 inches.
1 hack-saw frame, "Star," adjustable, No. 10.
2 hack-saw blades, 10 inches, dozen, Milford.
1 cable dresser, dogwood.
1 stearine, ¼ pound, in metal can.
1 paper, gummed, 1½ inches wide ("Paster's"), pounds.
1 hammer, claw, with handle, Atha, No. 41½.
1 hammer, plumber's, 18 ounces, with handle, No. 240*a* Atha.
1 tool bag, canvas, leather bottom, 20 inches, W. E. Co., No. 15201.
250 paper sleeves, $\frac{3}{16}$ inch by 3 inches.
2 cotton strips, ¼-inch, in rolls, 5 inches diameter.
6 cloths, wiping, moleskin, two 6 inches square; two 3 inches square; and two 5 inches square.
1 file, hand, smooth, 6 inches, with handle.
1 file, half-round, bastard, 6 inches, with handle.
1 rasp, 12 inches, with handle, cabinet.
1 rule, 2-foot, folding, boxwood, brass bound, No. 62½, C. S. Co.
1 pliers, pair, 8 inches, U. D. F. & T. Co., No. 50, or P. S. & W., No. 40.
1 snips, No. 10, Compton.
3 drift pins, 1¼ inches, 1½ inches, 2 inches.
1 torch, gasoline, Clayton & Lambert, No. 32.

PIPE FITTER'S CHEST.

[This chest is manufactured under specification No. 276.]

The pipe fitter's chest is issued whenever work in connection with fire-control or post-telephone systems require the installation of iron conduit. Tools necessary in cutting and threading iron conduit from one-half to 2 inch sizes are included in the equipment of this chest. The chest also contains a pipe former, for use in bending iron conduit in sizes from one-eighth inch to 1¼ inches. This chest is shown in figure 8–19.

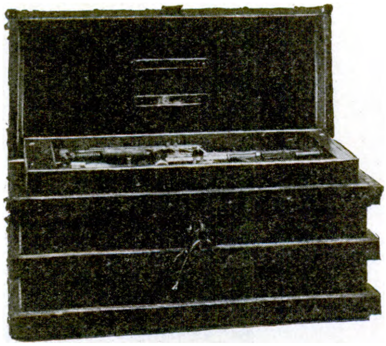


Fig. 8–19.—CHEST, TOOL, PIPE FITTER'S.

Name plate.

PIPE FITTER'S CHEST,

U. S. SIGNAL CORPS.

No. ——.

Equipment.

2 pipe wrenches, "Trimo," 18 inches.
1 pipe vise, combination, Prentiss, swivel base, 3½-inch reversible jaws.
1 pipe cutter, "Trimo," No. 2, ½ inch to 2 inches.
1 stock for dies, Duplex or Oster, No. 3½, ½ inch to 2 inches, adjustable, with quick-opening and self-centering dies and guides.
1 set of dies for above stock, ½ inch to 2 inches.
1 oil can, malleable iron, 5 ounces.
1 burring reamer, for brace, "Lightning," 1¼ inches.
1 pipe former, ⅛ inch to 1¼ inches, Vanderman, No. 1.
1 file, half-round, bastard, 6 inches.
1 rasp, smooth, 10 inches.
1 file, hand, smooth, 10 inches.

POST TOOL CHEST.

[The post tool chest is manufactured under specification No. 350.]

The post tool chest is for general use. It may be issued to coast defense artillery engineers, for use in maintenance of fire-control and post-telephone systems. The equipment consists of tools most frequently used in maintaining electrical installations. Figure 8–20 illustrates the post tool chest.

Name plate.

POST TOOL CHEST.

SIGNAL CORPS, U. S. ARMY.

No. ——.

3 bits, $\frac{12}{16}$-inch, $\frac{8}{16}$-inch, and $\frac{4}{16}$-inch, Irwin.
1 brace, ratchet, ball-bearing, 8-inch throw, Millers Falls Co., No. 33.
1 chisel, socket, ¾-inch, beveled edge, Jennings, No. 70.
1 chisel, cold, ¾-inch.

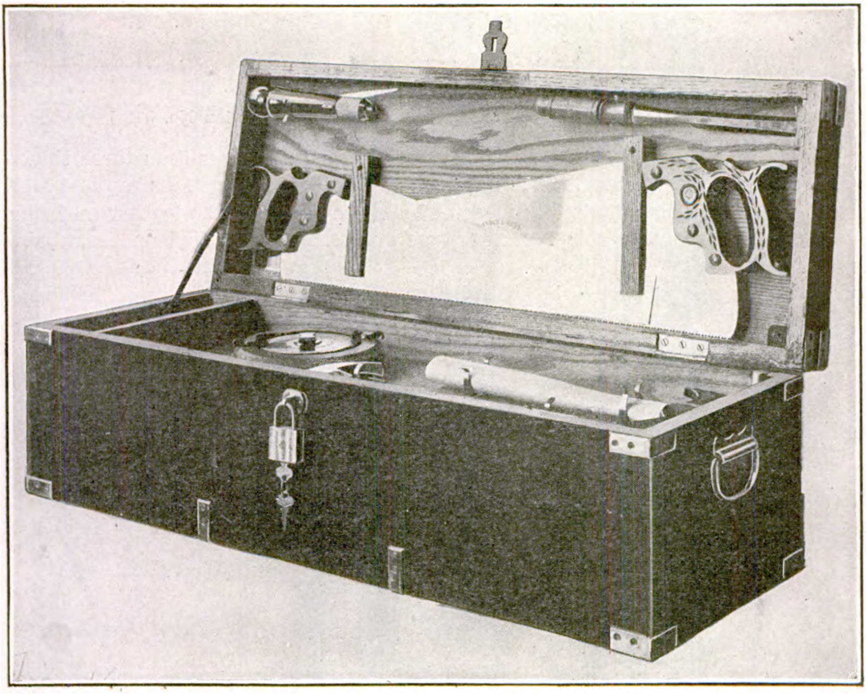


Fig. 8-20.—CHEST, TOOL, POST.

1 file, "Arcade," with handle, 6-inch round, bastard.
1 file, saw, with handle, 8-inch D. E., "Arcade."
1 file, 8-inch, clear edge, "Arcade," with handle, hand, bastard.
1 hammer, claw, "Atha," No. 41½.
1 holder, tool, Millers Falls, No. 5, containing the following:
  1 4-inch saw.
  1 8-inch saw.
  2 screw drivers.
  1 chisel.
  1 gouge.
  2 awls.
  1 gimlet.
  1 three-cornered file.
  1 reamer.
1 hatchet, claw, 4½-inch blade, "Keen Kutter," A. C. 3.
1 knife, draw, 14-inch blade, "Keen Kutter," telegraph pattern.
1 oil stone, "Pike," soft, Arkansas, 5 inches, mounted.
1 plane, iron, "Keen Kutter," No. 4c.
1 pliers, pair, 6-inch side-cutting, U. D. F. & T. Co., No. 50, or P. S. & W., No. 40.
1 rule, 2-foot, fourfold, boxwood, brass bound, C. S. Co., No. 62½.
1 saw, 20-inch, crosscut, 9 Pts., Disston's.
1 saw, 24-inch, crosscut, 8 Pts., Disston's.
1 screw driver, "Perfect," 6-inch.
1 square, graduated, 9-inch, "Stanley," No. 20.

1 tape, metallic, "Lufkin," 50-foot, No. 503.
1 wrench, screw; 10-inch (opening in jaws 1 11/16 inches), Coe's or Bemis & Call's, No. 54.

SERVICE TOOL BAG.

[The service tool bag is manufactured under specification No. 312.]

The service tool bag is constructed of fair leather, not less than three thirty-seconds inch in thickness. It is equipped with suitable carrying strap and lock. Cleats for holding a limited number of tools are sewed to the leather on inside of back, and considerable room for small miscellaneous supplies is available within the bag.

The service tool bag is issued with or without tools and may be furnished any Signal Corps construction parties. It is also issued for use in maintenance of fire-control and post-telephone systems. Figure 8–21 illustrates the service tool bag.

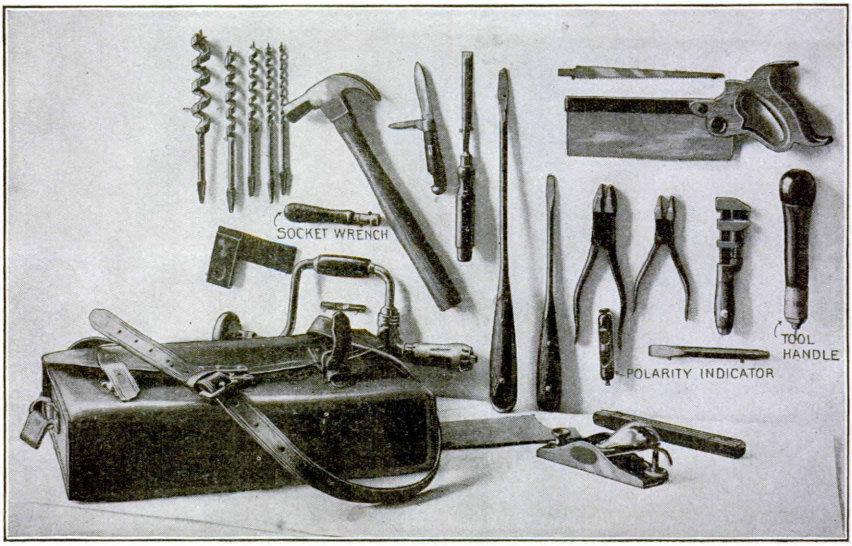


Fig. 8–21.—BAG, TOOL, SERVICE.

Equipment.

1 try-square, steel, 4-inch blade, Stanley, No. 12.
1 chisel, cold, ½-inch.
1 chisel, wood, ½-inch socket blade, iron, ring-topped handle, Jennings, No. 15.
1 hammer, claw, 16-ounce, Atha, No. 41½.
1 handle with tools, No. 5, Millers Falls Co.
1 knife, Empire Knife Co.'s No. 1013.
1 level, pocket, spirit, 3-inch, No. 31, Stanley's.
1 plane, block, Stanley, 6-inch, No. 18.
1 pliers, pair, 6-inch, side cutting, U. D. F. & T. Co., No. 50, or P. S. & W., No. 40.
1 pliers, pair, 8-inch, side cutting, U. D. F. & T. Co., No. 50, or P. S. & W., No. 40.
1 4-foot rule, folding, boxwood, 8 parts, Stanley, No. 404.
1 saw, back, 10-inch, Disston's.

1 screw driver, Perfect, H. D. S. Co., 6-inch.
1 screw driver, Perfect, H. D. S. Co., 10-inch.
1 solder, resin core, pound.
1 wrench, screw, Coe's forged, 6-inch monkey wrench, or Bemis & Call's No. 54.
1 wrench, socket, for telephone apparatus, 4-inch.
1 ratchet brace, Millers Falls, 8-inch throw, No. 33.
1 $\frac{1}{4}$-inch,
1 $\frac{3}{8}$-inch,
1 $\frac{1}{2}$-inch, } Irwin auger bits.
1 $\frac{5}{8}$-inch,
1 1-inch,
1 polarity indicator, M. E. S. Co., No. 3321.

INSPECTOR'S POCKET KIT.

[The inspector's pocket kit is manufactured under specification No. 186.]

As the name implies, the inspector's pocket kit is of such size that it may be conveniently placed in a pocket of clothing. The tools furnished with this kit are only those which may be required for the repair of an instrument or inside line.

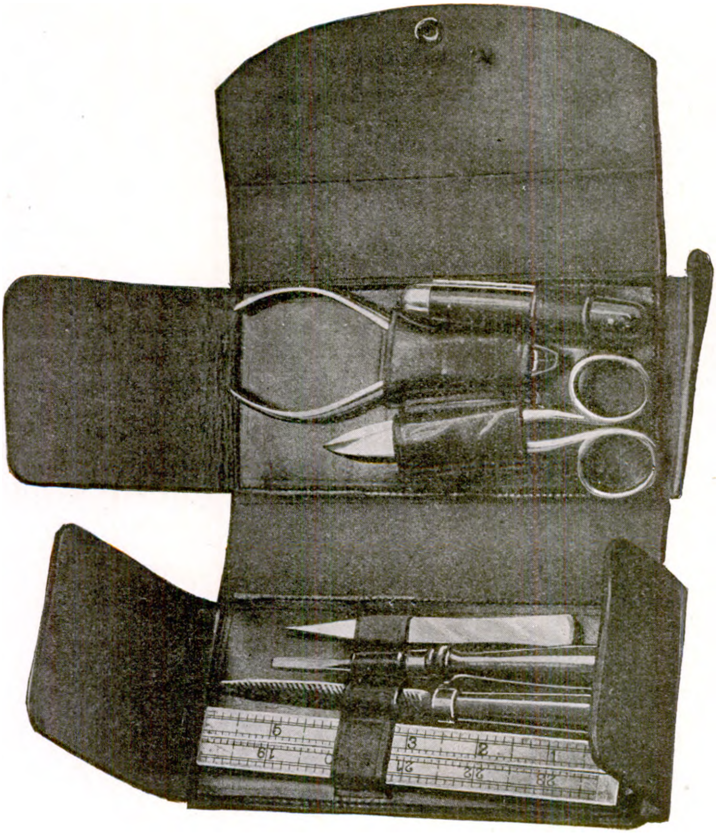


Fig. 8–22.—KIT, TOOL, INSPECTOR'S POCKET.

The case is made of leather which folds in such a manner that when closed it is impossible for the contents to become dislodged from the case. The inspector's pocket kit is shown in figure 8–22.

Marking.

The carrying case has stamped into the leather the following:

INSPECTOR'S POCKET KIT,
U. S. SIGNAL CORPS.
No. ——.

Equipment.

1 screw driver and skinning knife, combined, with safety spring, Empire, No. 372.
1 scissors, electrician's, 5-inch, nickeled, J. Wiss & Sons.
1 pliers, 5-inch, side cutting, nickeled, pair, U. D. F. & T. Co., No. 1250, or P. S. & W., No. 1240.
1 file, bastard, 3-inch, half round, with handle
1 tweezers, 4½-inch, nickeled, pair.
1 screw driver, 2-inch, Tuck's Giant.
1 rule, 2-foot, narrow, fourfold, boxwood, brass bound, C. S. Co., No. 62½.

Electric drills, spring hammers, and other special tools are kept in stock at Signal Corps general supply depots, and are issued to construction parties when the magnitude of the work involved warrants such action. These special tools should be invariably returned to supply depot from which received, upon completion of the work for which they are issued, unless instructions for different action are issued by the Chief Signal Officer of the Army.

MOLDINGS.

Three types of wooden molding are supplied by the Signal Corps where it is desired to conceal inside wiring by this means. The sizes of these three types, which are designated A, B, and C, respectively, are shown in figure 8–23.

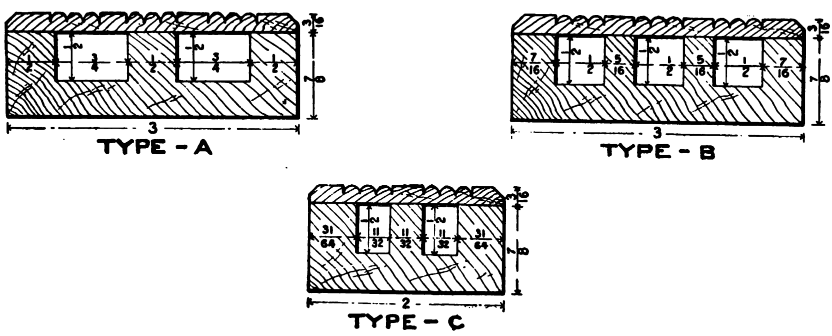


Fig. 8–23.—MOLDING, STANDARD TYPES.

GROUND RODS.

Three types of ground rods are now issued by the Signal Corps, type A, type D, and type E. Other types have been issued in the past but are now considered obsolete. The type A ground rod consists of a ⅝ inch by 5 feet heavily galvanized iron rod, pointed at one end and equipped at other end with a short piece of copper wire, soldered to the rod. They are supplied for making ground connections for post telephone systems employing aerial line construction where it is impracticable to connect to a water pipe or wherever it is desired to establish a permanent ground connection. Where ground connections are obtained by attachment to water pipes, suitable clamps for the purpose are furnished.

The type D ground rod is 9 inches in length, made of hexagonal steel one-fourth inch diameter (across flats), pointed at one end and bent into circular form at the other. The circular end is equipped with a machine screw for connection. This ground rod is used almost exclusively for making ground connection for the service buzzer and forms a part of the "ground rod and connector" which is furnished as a part of the service buzzer.

The type E ground rod consists of a round galvanized iron rod 24 inches long, pointed at one end and equipped with a loose iron ring at other. The rod is slightly flattened approximately three-fourths inch below where ring is attached and a machine screw for making line connection is threaded through the rod. The loose ring is used for withdrawing the ground rod. This type is for use in connection with camp telephone systems or wherever a temporary or semipermanent ground connection is desired.

KNIFE SWITCHES.

Knife switches of various types and sizes are furnished upon receipt of requisition, when approved by the Chief Signal Officer of the Army.

MOGUL PAINT.

This paint is similar to black asphaltum paint, and is used on the exterior of conduits, junction boxes, and other surfaces exposed to the weather. Storage battery stands, when constructed, should be given at least two coats of this paint.

SOLDER.

Resin core solder consists of a round wire of solder, with aperture through center filled with powdered resin. The resin acts as a flux, and no injurious effects result from its use. Resin-core solder should always be used in soldering splices and connections where small wire is involved.

Half-and-half solder is supplied for soldering on lugs and similar work.

Plumbers' solder is supplied for wiping joints.

BRIDLE RINGS.

Bridle rings of various sizes are furnished for supporting bridle wires between aerial lines and cable pole boxes. They are also used where it is desired to support one or more twisted pair wires for a considerable distance along the side or under the cornice of a building.

The approved bridle ring is of iron, coated with enamel. Figure 8–24 illustrates the bridle ring.

Fig. 8–24.—RINGS, BRIDLE, ENAMEL COATED.

PHOTOGRAPHY.

For service in the field, where a photographic outfit is required, the Signal Corps will supply a high-grade camera and holders, of a type intended for the use of film packs or film rolls, and taking a picture 3¼ by 4¼ inches. Film packs or rolls will also be supplied, but no developing or printing equipment will be furnished with them except under special circumstances. When all the films in the pack or roll have been exposed they should be put in strong opaque wrapper and mailed immediately to the Chief Signal Officer of the Army, stating that they are exposed films to be developed and inclosing a statement of the subjects. These will be developed in the signal office, Washington, by an expert photographer, and the person sending them will be furnished one unmounted print of each, enlarged or of size of negative. Pictures which are of special interest and value will be enlarged from the negatives to 8 by 10 size and placed in the official album.

All photographic negatives of instruments, equipment, etc., known as "technical negatives," will be filed in the office of the Chief Signal Officer of the Army.

When forwarding photographic prints to the office of the Chief Signal Officer of the Army for file, they should be sent, as far as practicable, unmounted.

It is not intended that photograph plates, films, chemicals, or other materials liable to deterioration be kept in stock at general supply depots of the Signal Corps.

SCREW ANCHORS.

Screw anchors are used where it is desired to fasten telephones, other apparatus, conduit, etc., to walls of concrete or brick. In using these anchors it is necessary to first drill a hole of correct diameter by means of drills furnished with tool kits. After hole has been drilled proper depth, the screw anchor is inserted and wood screw or lag screw of proper dimensions is screwed into the interior of the anchor. The anchor is of such shape that as the wood screw passes into the anchor the latter is expanded.

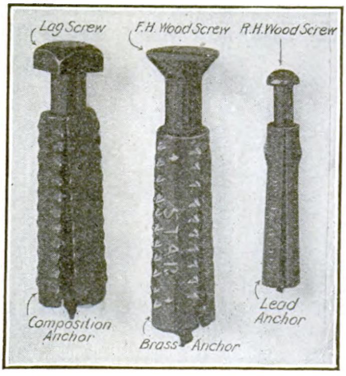


Fig. 8–25.—ANCHORS, SCREW, COMPOSITION.

The strength of these anchors is ample for use in the installation of telephones and similar light apparatus. It must be understood, however, that the holding power of them is limited to the strength of thread in the lead or composition, consequently they are not as strong as a lag bolt properly cemented into the wall.

The holes drilled for the anchor should be about one-fourth inch deeper than the length of the anchor and of such size as to provide an easy driving fit. Great care should be exercised in installing the anchor in order to prevent the screw from passing entirely through, thereby coming in contact with bottom of the hole in wall. The anchors are furnished in various sizes, those most commonly used being for Nos. 10, 11, or 12 wood screws, and for a three-eighths-inch lag screw.

The cutter toggle is supplied for use in the installation of conduit, cables, etc., on tiled walls. It has been found to be a very satisfactory device for the installation of signal and similar apparatus on walls which are lined with tiling.

SWITCHBOARDS.

Switchboards:
- Telegraph—
  - 2-line.
  - 8-line.
  - Jacks, spring.
  - Plugs—
    - With cord, for jack spring.

Switchboard, post telephone, common battery:
- 50-line, visual signals, fully equipped and complete with arrester cabinet.
- 100-line, visual signals, fully equipped and complete with arrester cabinet.
- 100-line, lamp signals, fully equipped and complete with arrester cabinet.
- 200-line, lamp signals, fully equipped and complete with arrester cabinet.
- 300-line, lamp signals, fully equipped and complete with arrester cabinet.
- 600-line, lamp signals, multiple, fully equipped and complete with arrester cabinet.
- Repair parts for—
  - Bell, night.
  - Buzzer, complete.
  - Cabinet arrester—
    - For 50-line common battery switchboard.
    - For 100-line common battery switchboard.
    - For 200-line common battery switchboard.
    - Repair parts for—
      - Line terminal, strips of 10 pair.
      - Protector—
        - Carbon, pairs for.
        - Complete, in strips of number of pairs required, W. E. No. 84.
        - Heat coils, for.
        - Micas for
        - Strips, wood—
          - For mounting line terminals (give length of strip).
          - For mounting protector (give length of strip).
- Coils, impedence or retardation, for operator's set.

Switchboard, post telephone, common battery—Continued.
- Condenser—
  - 1-microfarad, cord circuit.
  - 2-microfarad, for magneto line.
  - 2-microfarad, for operator's set (for either primary or secondary circuit).
- Cord, connecting—
  - 2 or 3 conductor (give length of cord and style of terminals)—
    - 2-conductor, 72-inch.
    - 3-conductor, 72-inch.
- Fuses—
  - Baby, 5-ampere.
  - Mica, 1-ampere.
- Generator—
  - Complete.
  - Crank for.
- Handle, hard rubber, for ringing and listening keys.
- Induction coil for operator's set.
- Jack, line—
  - Common battery, complete (single or in strips of 10).
  - Magneto, complete.
- Jack, operator.
- Key—
  - Night bell.
  - Ringing and listening.
- Lamp—
  - Pilot—
    - 24 or 30 volt.
    - Cap for.
    - Socket for.
  - Supervisory—
    - 24 or 30 volt.
    - Cap for.
    - Socket for.
- Plug—
  - For connecting cord.
  - Operator.
- Receiver—
  - Cap for.
  - Cord for (give length and style of terminals)—
    - Cord, 72-inch, no plugs, 2-pin and 2-washer terminals, for.
    - Diaphragm for (give diameter).
  - Single head.
- Relay—
  - Cord—
    - Complete.
    - Coils for.
    - Pilot.
      - Coil for.

Switchboard, post telephone, common battery—Continued.
- Relay—Continued.
  - Signal—
    - Line—
      - Common battery, complete.
      - Coil for common battery.
      - Magneto, complete with mounting.
      - Magneto, coil for
    - Supervisory—
      - Coil for.
      - Complete with mounting.
  - Terminals—
    - Cord, shelf.
    - Line.
  - Transmitter—
    - Complete.
    - Cords for (give length, style of terminals, and state whether 1 or 2 conductor).
    - Mouthpiece for.

      NOTE.—In requesting repair parts of switchboards and protector cabinet, give manufacturer's name, type, and, if practicable, Signal Corps serial or order number.

Switchboard, post telephone, local battery, 150-line.

Switchboard, post telephone, L. B., 50-drop.
- Bell, night.
- Bell, night, switch for.
- Cabinet, arrester, 50-line.
- Coil, induction, operator's.
- Cord, connecting (72-inch), without plugs.
- Generator, hand.
- Generator, hand, crank for.
- Jacks, line, complete.
- Key, ringing and listening, complete.
- Plug, for connecting cord.
- Receiver, single head—
  - Complete.
  - Cord for, without plug.
  - Diaphragm for.
- Signals, line—
  - Complete.
  - Coils for.
- Signal, supervisory—
  - Complete.
  - Coils for.
- Transmitter—
  - Complete.
  - Cord for.
  - Mouthpiece for.

Switchboards, miscellaneous:
- 20-line, telephone, portable, magneto type.
- Power—
  - Complete, for use with motor generator.
  - Type 2.
  - Type 4.
  - With distributing frame, for fire-control switchboard room.
    - Frame, distributing, for.

Switchboards, telephone, charging panel, types 1 to 5:
- Type 1.
- Type 2.
- Type 5.

(In requesting repair parts for any of the instruments mounted on this board, the data shown on name plate of that particular instrument should be entered.)

CAMP TELEPHONE SWITCHBOARD.

This portable telephone switchboard was designed by the Signal Corps and is the result of a development which has been in process a number of years. It is installed at camps in connection with administration telephone systems and has a capacity of 40 lines.

The case which contains the switchboard proper is of basswood, lined inside and out with fiber. All of the component parts of the switchboard proper are mounted upon an iron frame, which may be withdrawn from case by removing four screws. When this switchboard is set up for operation, it is supported by four legs, which are telescopic and consequently adjustable. By an opening in the bottom, the cord weights and cords are allowed to protrude through bottom, assuming the usual position of the cords of the ordinary commercial switchboard. The rear of the switchboard case is hinged, and when opened access may be had to a very compact form of telephone-line protectors. Lines may be very quickly connected to these protectors, as each connection is made by means of a Fahnestock clip, it being merely necessary to depress a spring, insert wire, and release spring to make connection. Each protector consists of two carbon blocks and dielectric and a suitable fuse, all of which is considered an efficient telephone-line protector.

On the front of the switchboard is mounted a clock. No key is required to wind it, it being merely necessary to revolve a disk in order to wind. The transmitter is of suspended type and is supported by a metal arm which folds back and locks when the switchboard is not in use.

When this switchboard is prepared for transportation or for storage, the legs which support the switchboard are telescoped to their shortest length and are placed in rear of case, suitable mooring for them being provided therein. The upper part of the case, which is detachable, is placed into position and fastened. The cord weights and cords are placed in a compartment provided for that purpose, and the switchboard closely resembles a small chest. The accompanying illustration shows the switchboard ready for operation and ready for transportation or storage.

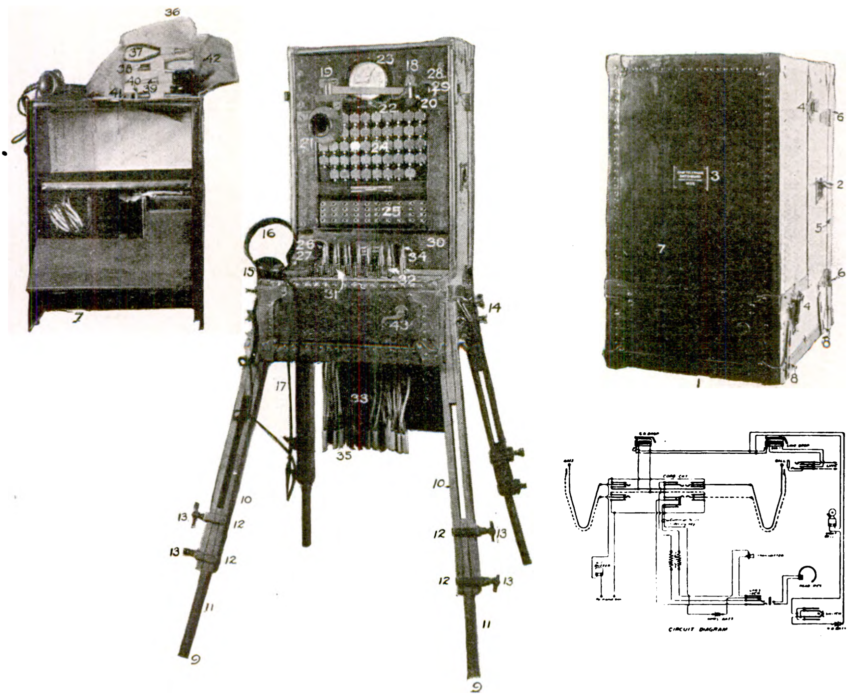


Fig. 8–26.—SWITCHBOARD, CAMP TELEPHONE.

Part No.	Name.	Reference No.
1	Case complete	1
2	Case, handle for	2
3	Case, name plate	3
4	Case, trunk catch for	4
5	Case, rear cover, complete	5
6	Case, rear cover, hinge for	6
7	Case, front cover for	7
8	Case, leg socket for	8
9	Leg, telescopic	9
10	Leg, telescopic, upper section	10
11	Leg, telescopic, lower section	11
12	Leg, telescopic, clamp complete	12
13	Leg, telescopic, clamp screw for	13
14	Leg, telescopic, wing nut and screw	14
15	Single head receiver	15
16	Single head receiver, headband for	16
17	Single head receiver, cord for	17
18	Receiver, cap for	....
19	Transmitter bracket complete	18
20	Transmitter bracket, catch for	19
21	Transmitter bracket, hinge for	20
22	Transmitter complete	21
23	Transmitter, cap for	....
24	Transmitter, cord for	22
25	Clock	23
26	Line signals and mounting (strips of 10), give numbers	24
27	Line signal coil	....
28	Line signal shutter	....
29	Line jack and mounting (strips of 10), give numbers	25
30	Receiver jack (1)	26
31	Receiver jack plug	27
32	Transmitter jack (1)	28
33	Transmitter jack plug	29
34	Key, night alarm	30
35	Key, night alarm, handle for	....
36	Key, ringing complete	31

(Continued on next page.)

(Parts list—Continued.)

Part No.	Name.	Reference No.
37	Key, ringing, handle for	
38	Key, ringing and listening	32
39	Key, ringing and listening, handle for	
40	Cord, connecting	33
41	Cord, connecting plug complete	34
42	Cord, connecting, weight	35
43	Tool kit complete	36
44	Tool kit, snipe nose pliers	37
45	Tool kit, diagonal pliers	38
46	Tool kit, screw driver, large	39
47	Tool kit, screw driver, small	40
48	Tool kit, wrench	41
49	Tool kit, case for	42
50	Magneto complete	
51	Magneto, crank handle	43
52	Magneto, gear	
53	Magneto, pinion	
54	Magneto, contacts	
55	Magneto, armature	
56	Lightning arrester complete	
57	Fahenstock clip	
58	Carbons and dielectrics	
59	Fuses, line	
60	Buzzer, ringing	
61	Battery (2 No. 6 dry cells per set)	

TELEPHONES.

Wall, common battery (auto pay station).
Field.
Common battery:
- Desk set, complete.
  - Repair parts for—
    - Bell set, complete.
    - Binding posts, locknut.
    - Condenser, 2-microfarad, complete.
    - Cord, main (state whether 2 or 3 conductor).
    - Cord, receiver.
    - Desk stand, complete.
    - Induction coil, complete.
    - Receiver—
      - Cap for.
      - Diaphragm for (give diameter).
      - Hand, complete.
      - Shell for.
    - Ringer—
      - Coils for.
      - Complete with gongs.
      - Gongs for.
    - Transmitter—
      - Complete.
      - Knuckle joint for.
      - Mouthpiece for.
- Wall set, complete, wooden case.
- Wall set, metal case.
  - Repair parts for—
    - Binding posts, locknut.
    - Coil, induction, complete.
    - Condenser, 2-microfarad, complete,

Common battery telephones.
Wall set, metal case—Continued.
Repair parts for—Continued.
Hook, switch—
Complete, but without hook lever.
Hook lever for.
Receiver, hand—
Cap for.
Complete.
Cord for.
Diaphragm for (give diameter).
Shell for.
Ringer—
Coils for.
Complete, with gong.
Gongs for.
Transmitter—
Complete.
Arm and base.
Mouthpiece for.

Telephone, local battery:
Desk set, complete.
Repair parts for—
Bell sets, complete.
Binding posts, locknut.
Cord for receiver.
Cord, main (state whether 3 or 4 conductor).
Desk stand, complete.
Generator—
Complete.
Handle for.
Induction coil, complete.
Receiver, hand—
Cap for.
Complete.
Diaphragm for (give diameter).
Shell for.
Ringer—
Coils for.
Complete, with gongs.
Gongs for.
Transmitter—
Complete.
Heads (knuckle joint).
Mouthpiece for.
Wall set, complete.
Repair parts for—
Binding posts, locknut.
Hook switch—
Complete, but without hook lever.
Lever for.
Induction coil, complete.

Local battery telephones:
- Wall set, complete—Continued.
  - Repair parts for—Continued.
    - Magneto generator—
      - Complete.
      - Crank for.
    - Receiver, hand—
      - Cap for.
      - Complete.
      - Cord for.
      - Diaphragm for (give diameter).
      - Shell for.
    - Ringer—
      - Coils for.
      - Complete, with gongs.
      - Gongs for.
    - Transmitter—
      - Arm and base.
      - Complete.
      - Mouthpiece for.

Common battery, fire control (metal case):
- Gun, C. B. F. C.
- Hand set.
- Head set.
- Plotter's set, C. B. F. C.
- Wall, C. B. F. C.
- Battery commander's, C. B. F. C.

Camp:
- Maintenance parts—
  - Hand set, complete.
  - Ringer.
  - Generator.
  - Cord, for hand set.

Field (now issued for target ranges only), maintenance parts:
- Blocks, hard rubber—
  - Receiver terminal.
  - Transmitter terminal.
- Cases, wood.
- Clips, brass, induction coil terminal.
- Coils—
  - Induction.
  - Receiver.
  - Ringer, 500-ohm.
- Cords, telephone, connector.
- Corners, metal.
- Cover, generator crank opening.
- Cranks, generator.
- Cups, electrode, complete.
- Diagram, wiring.
- Diaphragm—
  - Receiver.
  - Transmitter.
- Disks, mica, transmitter.

Field telephone (now issued for target ranges only), maintenance parts—Contd.
- Fastener for cover.
- Gasket, soft rubber—
  - Switch opening.
  - Transmitter diaphragm.
- Generators, 3-bar, with cranks.
- Gongs, bell, with screws and brackets.
- Hand sets.
- Hinges, strap.
- Post, binding—
  - Line.
  - Lock nut.
  - Receiver terminal.
  - Transmitter terminal.
  - Wing nut.
- Ringer, 1,000-ohm.
- Rings, swivel, and plates.
- Shells, hard rubber, for hand receivers.
- Springs—
  - Switch, with platinum contact.
  - Transmitter, dampening.
- Straps, carrying, black leather, complete with buckles and rings.
- Terminals, coil.

WIRE.

A great percentage of all wire purchased by the Signal Corps is manufactured in accordance with Signal Corps specifications and is thoroughly tested by a competent inspector before being accepted.

DESIGNATION OF WIRE IN MILS.

Hereafter in all specifications, purchase orders, contracts, requisitions, and other communications concerning the purchase, inspection, and issue of all types of solid wires by the Signal Corps, reference will be made to the sizes of wires by stating the diameter in thousandths of an inch (mils) in accordance with the table of mils shown below.

1	2	3	1	2	3	1	2	3	1	2	3
Mils.	B.W.G.	B. & S.	Mils.	B.W.G.	B. & S.	Mils.	B.W.G.	B. & S.	Mils.	B.W.G.	B. & S.
460	0000	0000	128	10	8	36	20	19	10.0	33	30
410	000	000	114	12	9	32	21	20	8.9	34	31
365	00	00	102	....	10	28.5	22	21	8.0	35 and 36	32
325	0 and 1	0	91	13	11	25.3	23	22	7.1	37	33
289	2	1	81	14	12	22.6	24	23	6.3	38	34
258	3	2	72	15	13	20.1	25	24	5.6	....	35
229	4 and 5	3	64	16	14	17.9	26	25	5.0	39	36
204	6	4	57	17	15	15.9	27	26	4.5	40	37
182	7	5	51	18	16	14.2	28 and 29	27	4.0	....	38
162	8	6	45	....	17	12.6	30	28	3.5	....	39
144	9	7	40	19	18	11.3	31	29	3.1	....	40

NOTE.—The standard sizes in mils indicated are the sizes in the American wire gauge (B. & S.) rounded off to about the usual limits of commercial accuracy.

(See next page.)

The table shows (column 1) the War Department standard sizes, diameter in mils; and (column 2) the nearest commercial Birmingham wire gauge; and (column 3) Brown & Sharpe, or American wire gauge, for approximately the same size wire.

The difference between successive sizes is approximately a constant per cent of the size.

The following wires are supplied by the Signal Corps for radio-telegraph installations only and, inasmuch as they are special in character, will not be described herein. For detailed information concerning them, Signal Corps specification No. 416 should be perused.

High tension (one size only).
Low tension (five sizes).
Antenna (two sizes).
Antenna cord (one size only).
Counterpoise (one size only).
Silicon bronze (one size only).

Wires supplied by the Signal Corps in connection with installation of fire-control systems, post-telephone systems, small-arms target-range signaling systems, and lines of security and information are as follows:

Inside twisted pair (one size only).
Inside twisted triple conductor (one size only).
House (one size only).
Pot head (one size only).
Cross-connecting (two sizes 25.3 and 36 mils, respectively).
Rubber-covered (various sizes).
Fixture (two sizes, 40 and 51 mils, respectively).
Weatherproof (various sizes).
Bridle (one size only).
Outside twisted pair (two sizes, 64 and 81 mils, respectively).
Outside distributing, copper-clad (one size only).
Hard-drawn copper (various sizes).
Galvanized iron (various sizes).
Buzzer (one size only).
Field (one size only).
Office (two sizes, 36 and 51 mils, respectively).

A brief description of these wires in the order listed follows:

INSIDE TWISTED PAIR.

This wire consists of two separately insulated conductors twisted together. Each conductor is 40 mils diameter, soft copper, and is insulated with rubber compound and cotton braid. The braid of one conductor is red and of the other black.

This wire should invariably be used for the inside wiring of fire-control stations, and may be used for inside post-telephone system work at points where wire having unusually high insulation is desired.

INSIDE TWISTED TRIPLE CONDUCTOR.

This wire consists of three separately insulated conductors twisted together. Two conductors are exactly in accordance with those described under "Wire, inside twisted pair," immediately preceding. The third conductor is also similar except that it is supplied with a yellow braid.

This wire is used in fire-control stations where the head or hand set of a telephone is used at some distance from telephone instrument proper and connects the telephone with telephone terminal block to which is connected the head or hand set. It is also used between telephones proper and terminal boxes in fire-control stations when it is desired to use the earth as one side of the ringing (calling) circuit. It may also be used in connection with post telephone systems where a triple conductor wire having unusually high insulation is desired.

HOUSE.

This wire consists of two separately insulated conductors twisted together. Each conductor is 36 mils diameter, soft copper, and is insulated with rubber compound and cotton braid. Braids of conductors are furnished in various colors, but invariably one braid contains a tracer which consists of a thread of different color woven in the braid.

This wire should be used for inside wiring at post telephone substations, except substations which are fire-control stations.

POT HEAD.

This wire consists of two separately insulated conductors twisted together. Each conductor is 36 mils diameter, soft copper, and is insulated with rubber compound only, there being no braid supplied. A conductor may be traced by means of two ridges formed of the rubber compound of one conductor.

Formerly pot-head wire, with one conductor black (natural compound color) and the other red, was furnished. The colored compound becomes porous in a comparatively short time; consequently only pot-head wire with natural color compound should be used under any circumstances for permanent construction.

Pot-head wire is used in the construction of pot heads of all paper-insulation cable and may be used as cross-connecting wire in terminal boxes.

A special pot-head wire is furnished for use in the Tropics.

CROSS CONNECTING.

This wire consists of two separately insulated conductors twisted together. Each conductor is of soft copper, insulated with rubber compound and a flame-proof cotton braid. It is a commercial product and replaces the large wire with yellow and black braid formerly furnished as cross-connecting wire.

This wire should ordinarily be used for cross connecting in all station terminal boxes, but not in submarine cable terminal boxes. Cross connecting in submarine cable terminal boxes should be accomplished with fixture wire, described later.

RUBBER COVERED.

This wire consists of a single soft-copper conductor insulated with rubber compound and cotton braid impregnated with a waterproof compound. The sizes of the conductors most commonly used are 64 mils and 81 mils, respectively. Any commercial size of conductor can be furnished. This wire is used principally in fire-control switchboard rooms for power leads and in wire forms for power switchboards; also in the 51-mil size for wiring to apparatus at butts of small-arms target ranges.

FIXTURE.

This wire consists of a single soft-copper conductor insulated with a thin wall of rubber compound and a cotton braid impregnated with waterproof compound. It is furnished in two sizes, the conductor being 40 mils or 51 mils diameter. Fixture wire is used in wire forms for power or distributing switchboards and in cross connecting in submarine cable terminal boxes.

WEATHERPROOF.

This wire consists of a single hard-drawn copper conductor insulated with a triple cotton braid impregnated with a waterproof compound. It is used for extending aerial lines through the foliage of trees. It is also used in wire forms for power switchboards. Weatherproof wire is more rigid than "wire, rubber-covered," and for this reason only is it preferable for wire forms.

BRIDLE.

This wire consists of a single soft-copper wire 51 mils in diameter, insulated with rubber compound to an outside diameter of five-thirty-seconds inch, and covered with a closely woven braid impregnated with a weatherproof compound.

This wire can be furnished with two conductors, twisted together, if desired.

Bridle wire is used for connecting aerial lines with arresters in pole boxes, or wherever a 51-mil diameter wire with heavy insulation is necessary.

It differs from fixture wire in that the over-all dimension is greater.

OUTSIDE TWISTED PAIR.

This wire consists of two separately insulated conductors twisted together. Each conductor is insulated with rubber compound and a cotton braid impregnated with moisture-proof compound.

Two sizes of this wire have been furnished, the conductors being 81 mils and 64 mils in diameter, respectively.

Outside twisted pair is used in connecting aerial lines with substations and under certain conditions it may be used as aerial line, also for temporary work of various characters.

OUTSIDE DISTRIBUTING, COPPER CLAD.

This wire consists of two separately insulated conductors twisted together. Each conductor consists of a steel core upon which is welded a copper coat of uniform thickness. Each conductor is 45 mils diameter and is insulated with rubber compound and a closely woven cotton braid impregnated with moisture-proof compound.

Outside distributing copper-clad wire in a great measure supersedes the outside twisted pair described in the preceding item, it is smaller and lighter, but used for the same purposes.

HARD-DRAWN COPPER.

This wire consists of one noninsulated conductor of hard-drawn copper. It can be furnished in any of the commercial sizes, but smaller than 81 mils diameter should not be used for permanent lines. The 81 mils diameter size is suitable for practically all aerial lines constructed by the Signal Corps.

Copper line wire, hard drawn (bare).

Diameter.	Weight per 1,000 feet.	Weight per mile.	Resistance per 1,000 feet at 68°.	Resistance per mile at 68°.	Tensile strength.	Coil lengths.
Mils.	*Pounds.*	*Pounds.*	*Ohms.*	*Ohms.*	*Pounds.*	*Feet.*
182	100	529	0.323	1.71	1,550	1,000
162	79	419	.407	2.15	1,235	1,000
144	63	331	.513	2.71	980	2,640
128	50	262	.646	3.41	778	2,640
114	39	208	.815	4.30	617	2,640
102	32	166	1.028	5.43	489	2,640
91	25	132	1.296	6.84	388	5,280
81	20	105	1.635	8.63	307	5,280
72	15.7	83	2.061	10.88	244	5,280
64	12.4	65	2.599	13.72	193	5,280

GALVANIZED IRON.

This wire consists of one noninsulated conductor of iron wire, heavily galvanized. It can be furnished in any of the commercial sizes, but is usually supplied in the 81 or 80 mils diameter size for provisional fire-control or post telephone system lines, and is always furnished in this size for field lance-pole lines; 144 or 148 mils diameter size is usually furnished for permanent telegraph "long lines." There are three commercial grades of this wire, which are designated as follows: B, BB, and EBB. The EBB grade is supplied by the Signal Corps unless tensile strength is more important than conductivity for a given size.

In connection with fire control and post telephone systems, galvanized-iron wire should be used for aerial lines for provisional or temporary installation only.

Galvanized-iron wire.

Diameter.	Area.	Weight per 1,000 feet.	Weight per mile.	Breaking strength.	Resistance per mile at 68° F.	Length of coil.
Mils.	*Cir. mils.*	*Pounds.*	*Pounds.*	*Pounds.*	*Ohms.*	*Feet.*
289	83,521	219	1,160	3,480	4.05	1,000
258	66,564	175	920	2,760	5.08	1,000
229	52,441	138	726	2,178	6.44	1,000
204	41,616	108	576	1,728	8.12	1,320
182	33,124	87	458	1,424	10.19	2,000
162	26,244	69	363	1,089	12.87	2,000
144	20,736	54	287	861	16.28	2,640
128	16.384	43	227	681	21.21	2,640
114	12,996	34	179	537	25.98	2,640
102	10,404	27	144	432	32.46	2,640
91	8,281	22	115	345	40.80	2,640
81	6,561	17	91	271	51.56	2,640

BUZZER.

This wire consists of a single insulated conductor composed of two steel and one soft copper wires, each having a diameter of 12 mils before tinning. The insulation consists of a double wrap of cotton impregnated with an insulating compound. The finished wire has a diameter between 0.035 and 0.004 inch, and is furnished by manufacturers on metal spools which contain one-half mile of the wire. Buzzer wire is used exclusively in the field in hurriedly establishing communication with a given location. If practicable it should be recovered when it has served its purpose.

FIELD.

Field wire is a single insulated conductor made up of 10 steel wires and 1 soft copper wire. The copper wire is 28.5 mils diameter and each of the steel wires 12 mils diameter before tinning, diameter of conductor 54 mils.

The conductor is insulated as follows: First, with a serving of cotton, then a seamless rubber compound having a thickness of 0.024 inch. The rubber-covered wire is then covered with a smooth, closely-woven braid of cotton, saturated with a moisture repellent compound and given a wax polish finish. It is furnished in half-mile lengths on small wooden reels.

Field wire is used exclusively in the field in hurriedly establishing communication with a given location and is usually paid out from a wire cart designed for the purpose. It is also used in semipermanent linework where it may be supported by means of lance poles.

Splicing field wire.—When field wire has been broken or cut, it will necessarily have to be spliced. Splices in field wires may be either temporary or permanent in character. If the wire is severed while in use, the lineman should locate the fault and complete the splice as quickly as possible. A temporary splice may be made as follows: The two ends of the severed wire having been caught up the ends are scraped of insulation (skinned) after a square knot has first been tied by knotting the two ends of the wire together. This knot is made to take the strain off of the splice. Care in making the square knot should be observed, so that a granny knot may not result. After knotting the wire the skinned ends are then twisted tightly together.

As soon as convenient the wire should be gone over, the bad lengths cut out, and permanent splices made in place of the temporary ones. To make a permanent splice, skin off the insulation for about 4 inches on each end and separate the steel and copper strands, so that the two copper strands may first be wound tightly together. The copper may be distinguished from the steel by its greater pliability. The steel strands are now wound together, making the joint mechanically secure. Snap off the loose ends and solder the joint. Wind insulating tape tightly over the splice.

OFFICE.

This wire has a single soft copper conductor of either 36 or 51 mils diameter, insulated with a vulcanized rubber compound, covered with a close-filled polished cotton braid, and is furnished in 500-foot coils. It is used principally for inside wiring in connecting up telegraph instruments, electrc bells, etc.

MISCELLANEOUS WIRES.

In connection with making electrical measurements and for various purposes, the following wires are supplied under special approval:

- Magnet; specify mils in diameter, supplied in single or double cotton or silk insulation.
- Resistance; finished as follows—
  - Single cotton covered.
  - Double cotton covered.
  - Single silk covered.
  - Double silk covered.
  - Bare.
- Silicon, bronze, bare, 28.5 mils in diameter; supplied in ½-mile spools.
- German-silver, 30 per cent alloy; see note under table below.
- Climax; see note under table below.
- S. B., bare, 12.6 mils in diameter (Driver-Harris).
- German-silver, 18 per cent alloy; see table below.

To secure uniformity in units relative to items of wire, the following will be observed:

All galvanized iron wire to be in miles. (Fractions less than a half mile may be disregarded.)

All bare copper wire in feet.

All insulated copper wire in feet. (This includes outside and inside twisted pair, bridle, pothead, and office wire.)

Buzzer wire, in spools. (Each standard spool holds one-half mile.)

Fuse wire, in pounds.

Field wire, in miles.

Magnet wire, in pounds.

Messenger strand wire, in feet.

Resistance wire, in pounds.

Deep-sea sounding wire, in fathoms.

Seizing wire, in pounds. (This is a soft G. I. wire, 40 mils in diameter, for serving armor wires of D. S. cable.)

Annunciator wire, in pounds. (This is copper wire of about 36 or 40 mils in diameter, cotton and paraffin insulation.)

Table of lengths and resistances of standard spools "18 per cent" German-silver alloy resistance wire.

Diameter in mils.	Net weight, ounces per spool.	Feet per ounce, approximate.					Ohms per ounce, approximate.					Ohms per 100 feet, approximate.
		Double cotton.	Single cotton.	Double silk.	Single silk.	Bare.	Double cotton.	Single cotton.	Double silk.	Single silk.	Bare.	
32	4	19	19	20	20	20	3.5	3.5	3.5	3.6	4.0	18.4
25.3	4	29	30	30	31	32	8.7	9.0	9.0	9.1	10.2	30.0
20.1	4	45	48	49	50	51	21.0	22.0	22.0	23.0	26.0	47.0
12.6	2	100	115	120	125	130	120.0	135.0	139.0	145.0	165.0	119.0
10.0	2	150	175	185	195	200	286.0	332.0	345.0	362.0	416.0	189.0
8.9	1	180	220	230	245	260	432.0	519.0	537.0	524.0	662.0	239.0
8.0	1	220	270	285	300	325	658.0	807.0	840.0	904.0	1,050.0	295.0
7.1	1	270	340	350	383	410	992.0	1,250.0	1,310.0	1,420.0	1,680.0	374.0
6.3	1	320	410	440	480	520	1,490.0	1,930.0	2,030.0	3,530.0	4,230.0	476.0
5.6	1	370	500	540	600	650	2,200.0	2,970.0	3,180.0	3,532.0	4,230.0	602.0
5.0	1	440	610	650	740	825	3,260.0	4,580.0	4,880.0	5,500.0	6,730.0	756.0
4.5	1	500	740	800	920	1,040	4,770.0	6,950.0	8,080.0	8,410.0	10,700.0	955.0
4.0	1	.....	.....	970	1,150	1,310	....	....	12,500.0	14,100.0	16,900.0	1,200.0
3.5	1	.....	.....	1,150	1,400	1,650	....	....	21,600.0	22,000.0	26,800.0	1,530.0
3.1	1	.....	.....	1,400	1,730	2,090	....	....	29,700.0	34,700.0	42,700.0	1,930.0

These values are approximate.

When "*Climax*" *resistance* wire is ordered, it should have a resistance approximately 2.777+times that of table. The other values for Climax wire are the same as above.

When 30 per cent German-silver wire is ordered, it should be estimated that its resistance is approximately 1.55 times that of 18 per cent wire.

Bare wire will be supplied in packages as above. Its resistance, etc., may readily be determined from data above.

Bare S. B. wire 12.6 mils in diameter, supplied in ounce spools (about 150 feet). Resistance, 2.1 ohms per foot.

MISCELLANEOUS FIELD EQUIPMENT.

WIRE CARRIER.

The wire carrier shown in figure 8–27 is used for paying out or recovering buzzer wire. It is also used for carrying the antenna and counterpoise of the Signal Corps portable radio sets. A carrier will hold one-half mile (same as metal reel) of buzzer wire, and canvas covers for them are supplied when needed. Wire can be conveniently paid out and recovered by means of these reels.

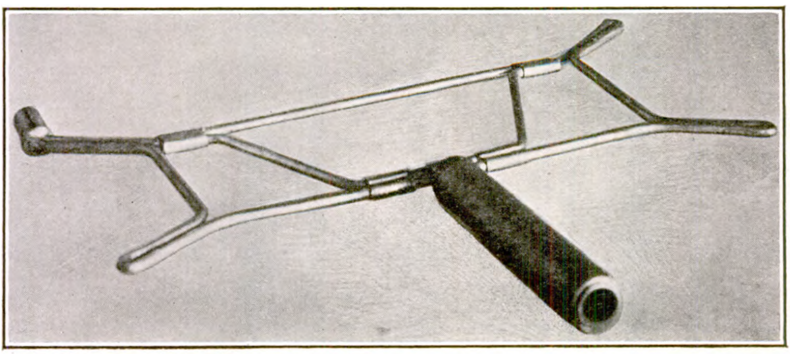


Fig. 8–27.—CARRIER, WIRE.

HAND REEL.

This apparatus may be used for paying out and recovering buzzer wire. It is so proportioned that the metal spool upon which buzzer wire is furnished fits the trunnions, and by means of a crank handle the spool can be revolved. Figure 8–28 shows the construction of this apparatus.

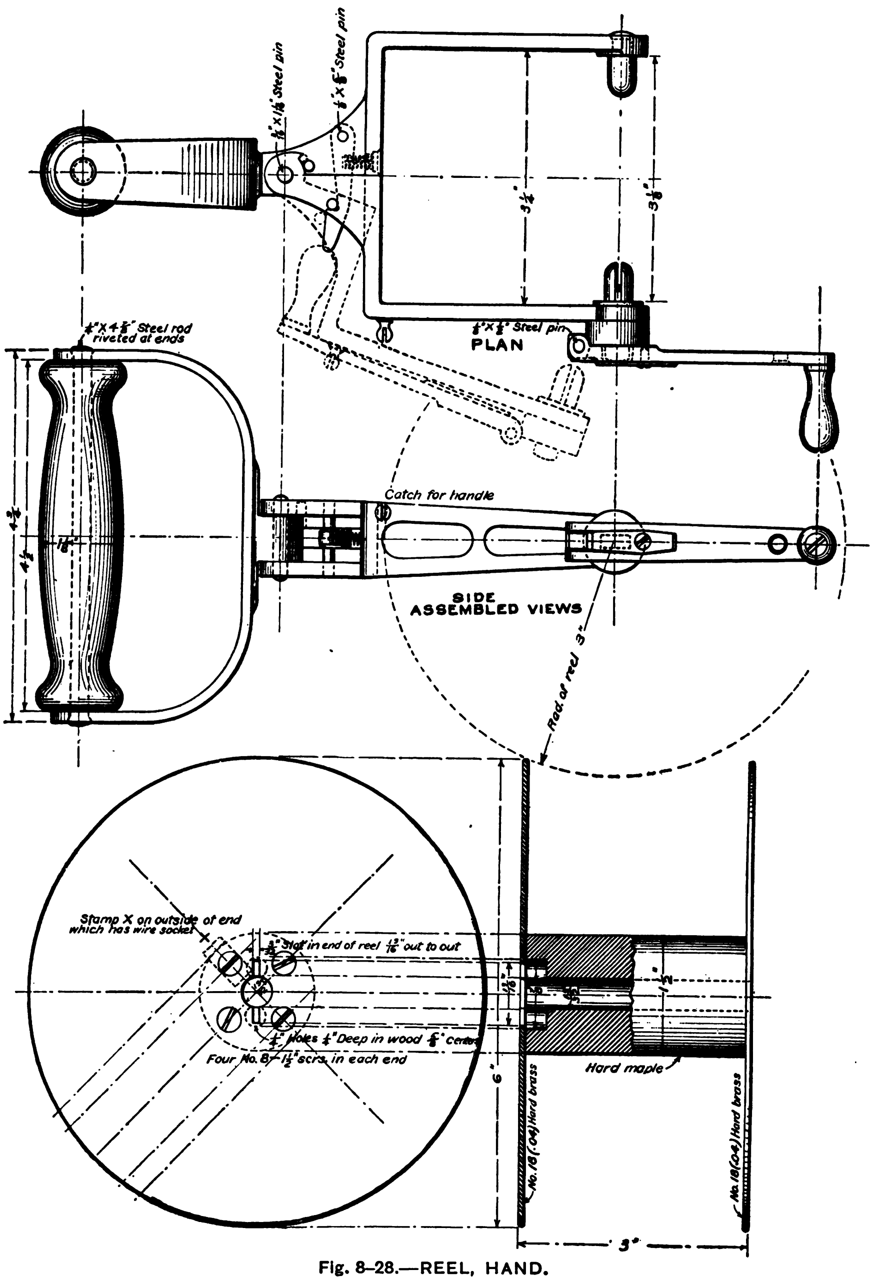


Fig. 8–28.—REEL, HAND.

BUZZER CONNECTOR.

Type A.—This form of connector is made of nickeled steel, and should be used for "clipping" on the buzzer wire and the 11-strand field wire. Extra studs should be kept on hand for repairs. These studs screw into the connector and may be removed if necessary. The flexible cord should not be knotted up or twisted, as this tends to break it. A type *A* connector is shown in figure 8–29.

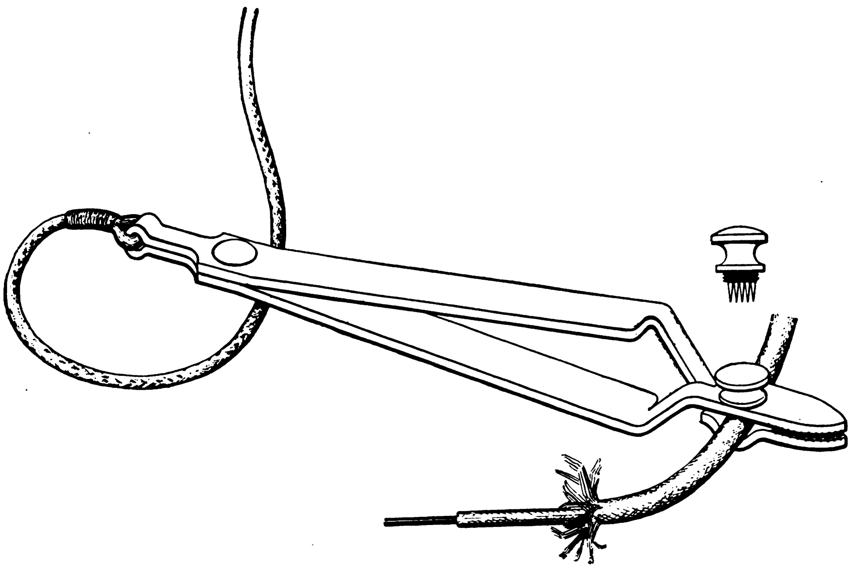


Fig. 8–29.—CONNECTOR, BUZZER, TYPE "A."

PIKES, WIRE.

The wire pike with model 1910 hook is shown in figure 8–30. This hook is made of malleable cast iron. The upper point is bent out three-fourths inch to facilitate picking up wire by mounted men. The hook proper is about one-half foot in length and is carried on a staff of straight-grained hickory. The complete pike is 9 feet in length.

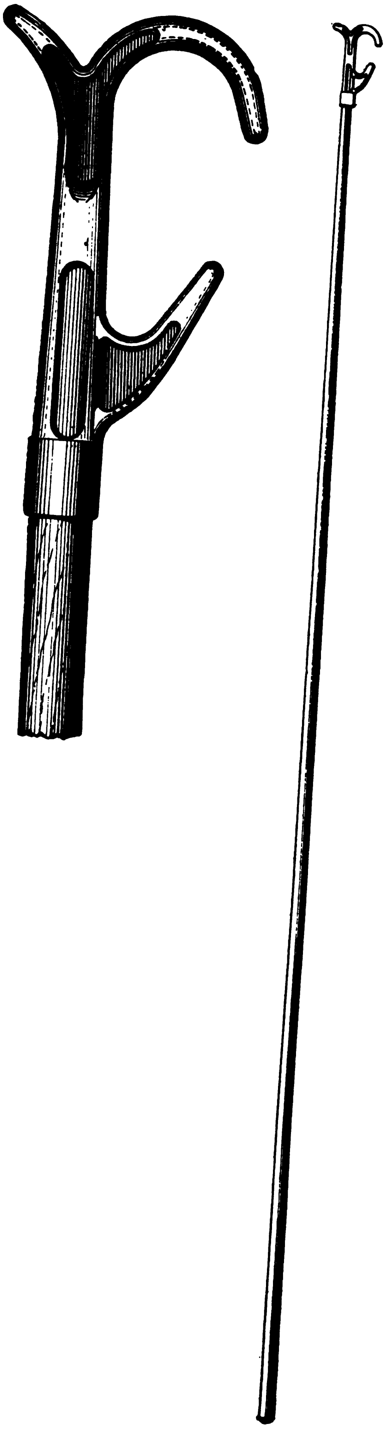
A hook with roller is now being tested, as continual use of a solid hook results in the wire wearing a deep groove in the metal.

MEGAPHONES, FIBER, 18-INCH.

The latest type of Signal Corps field megaphone is made of fiber, with aluminum mouthpiece and leather handle. These megaphones are 18 inches long and 9 inches in diameter at large end.

POLES, LANCE, AND INSULATORS.

These poles are usually made of well-seasoned, straight-grained pine or cypress, and are 13 feet 11 inches from tip to tip. The diameter of the pole at the butt is 2 inches, tapering to 1½ inches where it enters the head. The butt of the pole is shaped to a blunt point 3 inches long. The top is tapered to fit in a galvanized-iron head 3¾ inches long. This head is threaded externally to fit the ordinary glass or porcelain insulator. The end of the head



Figs. 8–30.—WIRE PIKE.

(372)

is threaded internally to receive a correspondingly threaded galvanized-iron rod upon which is molded a special mica composition insulator. These special insulators are of two types, the only difference in them being in the type of device for securing the wire. One is equipped with a bent galvanized-iron wire appliance called from its shape a "pig-tail insulator." The second is a U-shaped device similarly mounted, called a "clamp insulator." The clamp insulator is employed on about every fifth pole of a lance line, to prevent a longitudinal movement of the wire, while the pig-tail insulator is used upon the other poles. The lance pole weighs about 7 pounds and the galvanized-iron head with insulator about 3 pounds.

STANDARD SPECIFICATIONS.

The following index to standard specifications is correct to August 1, 1916. New specifications are added and old ones corrected from time to time. Those marked (*) are not intended for general distribution and are not in printed form:

A.

B.

C.

D.

E.

L.

M.

O.

P.

R.

V.

W.

An enumeration of all Signal Corps blank forms may be found in Signal Corps Manual No. 7, latest edition.

CHAPTER 9.

MISCELLANEOUS TESTS AND GENERAL INFORMATION.

MISCELLANEOUS TESTS.

The importance of testing, both for regularly ascertaining the condition of the lines with a view to anticipating breakdowns and as a means of locating faults when they occur, is something that should be recognized by all officers and enlisted men on duty in connection with maintenance of Signal Corps installations.

The following notes on cable testing and the location of faults where accurate instruments are not available will be found of great value where apparatus must be improvised.

The extensive use of short subterranean and submarine cables for fire-control, post-telephone, and submarine-mine systems generally, makes some method of easy testing desirable. Very often testing sets are not on hand. If on hand, they may be out of order or there may be nobody available who is sufficiently skilled in their use for location of faults. By far the most common class of faults is that due to defects in insulation. It is desirable to locate these in submarine cables, and very necessary in case of multiple-core cables buried in trenches or drawn into conduits, which, of course, prevents their being readily taken up for examination.

In the absence of better instruments, a fairly good idea of the insulation resistance of a cable may be arrived at by means of a battery and telephone receiver, as follows:

A telephone receiver (*T*) (fig. 9–1) is connected with the battery (*B*) of a few cells, the latter being connected with the cable armor at *C*. A well-insulated wire (*I*) is connected with the other terminal of the telephone. The ends of the conductor are prepared and insulated as above described. When the end of *I* is touched on the cable conductor a click is heard in the receiver. If after about one second it is touched again and no click is heard in the receiver, the insulation resistance, if one cell of battery is used, is above about 50 megohms; if two cells of battery, 100 megohms, and so on, for about the proportion of cells.

The click produced on first contact is due to the current rushing in to charge the cable; and if the insulation is good, in one second so small an amount of this charge will be lost by leakage that little or no sound will be produced by subsequent contacts, as cable will still be charged. Care should be taken that wire *I* and telephone terminal attached to it are well insulated, otherwise leakage from them may give false indications.

Having found the faulty conductors, the location of these faults may then be proceeded with by the method suggested below (figs. 9–2 and 9–3). It is applicable to cables having two or more similar conductors, or to a single-conductor cable when both ends are available, as when it is coiled in a tank or on a reel. It is the Murray loop test with a "slide wire" in which simple relations of resistance to lengths exist, owing to the uniformity of resistance along the wires in the cable conductors and slide wires, respectively. It is, in fact, a combination of several well-known instrument methods.

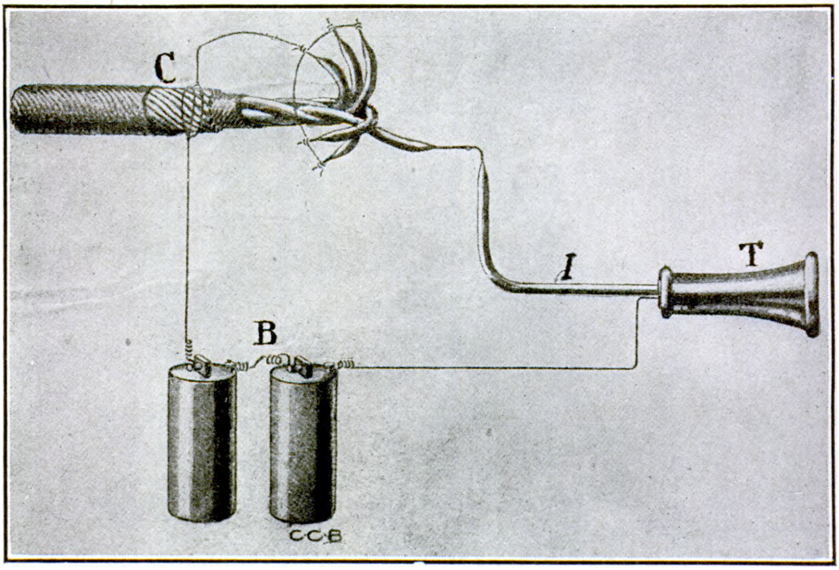


Fig. 9-1.—TEST, EMERGENCY, INSULATION.

To prevent serious errors care must be taken that one of the conductors in this test has sound insulation.

No resistance measurements are involved, and the only apparatus required is a few cells of battery, a telephone receiver, and from 10 to 50 feet of bare resistance wire. Of this latter about No. 28 "Climax" or "S. B." wire is suitable. However, if resistance wire is not to be had, fair results may be obtained by using No. 36 bare copper wire.

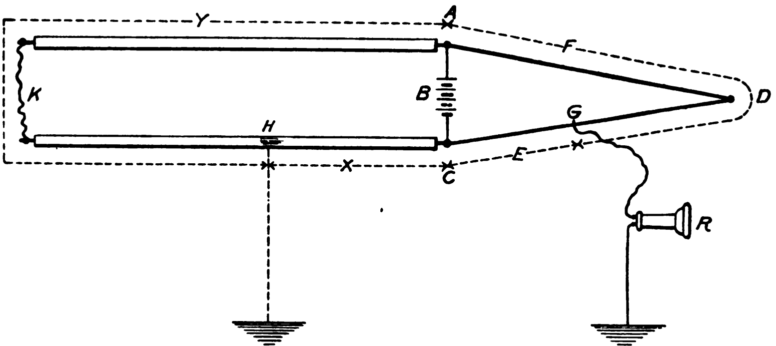


Fig. 9-2.—TEST, LOCATION OF FAULTS WITH IMPROVISED APPARATUS, USING A TELEPHONE RECEIVER.

First taking the case of a multiple-conductor cable, say 3,000 yards long, in which there are one or more conductors with defective insulation and at least one good one. Join the defective one to be tested with the good one at the distant end. Drive two small bright nails (*A* and *C* in fig. 9-2) convenient to the terminals of the conductors at the testing end and stretch from these a piece of the resistance wire around another nail (*D*) and back, making each equal branch of the wire *A D* and *C D* of such a length as to be some exact submultiple of the length of the cable being tested. For example, have each branch of the wire in this case three thousand thirty-seconds of an inch long. or $\frac{3000}{32}$ (93.75) inches. Join one of the two nails at the end of the cable terminals to the defective cable conductor, the other nail to the good conductor. Join one terminal of the telephone receiver *R* to the ground and the other terminal to a short wire, which will be used as a "searcher." Connect a few cells of battery *B* across the nails to which the cable terminals are attached. Now, putting the telephone receiver to the ear, feel along the resistance wire, which is attached to the defective conductor, with the searcher wire attached to the telephone. A point *G* will be found where the frying sound produced in the telephone will cease, and if the searcher wire be moved either way from this it will again become audible. Mark this point on the resistance wire, reverse the connections of the battery, and again find the point of silence. If it is not coincident with the first, take the mean position between them.

The distance of this point *G*, in *thirty-seconds of an inch*, from the nail *C*, to which the defective cable terminal is attached, is the distance in *yards* from the cable terminal to the fault.

It is evident that for short cables greater accuracy is secured by taking larger representative units in proportion for the resistance wires. For example, if the cable were 1,250 yards long, the units on the resistance wires could be sixteenths, and the wires be convenient in length: $\frac{1250}{16}=78\frac{1}{8}$ inches.

Care should be taken to stretch the resistance wires evenly and not wrap the loose ends back on the stretched portion, as that would destroy the uniformity of resistances throughout the length on which the assumed proportion depends.

In testing a defective single-conductor cable the two ends are joined to the resistance wire, as just stated, the *whole length* of the resistance wire being in some simple proportion to the length of the cable.

For example, if the cable is 1,980 yards long, the whole length of the resistance wire would be $\frac{1980}{32}$ or $\frac{1980}{16}$ inches, as desired—the greater length giving the result with greater accuracy. It will be readily seen that this and the former case are identical, as the "loop" formed by joining the distant ends of two multiple conductors is in this case replaced by the "loop" of the single conductor.

The method of securing ends of wires by nails is given to show with what ease and simplicity the necessary parts for the test may be set up. But even roughly and hastily set up, the test will locate faults with surprising accuracy if a sufficient length of resistance wire be used to eliminate small accidental irregularities in attachments of wires.

The test is a simple application of the Wheatstone bridge principle. It may be of interest to trace this out (fig. 9–2).

A K and *C K* are the two cable conductors joined at the distant end *K*. The lower one is defective at some unknown point *H*. The resistance wire *A D C* is joined up as shown with the cable conductors and battery *B*. The point of silence in the telephone is found at *G*. The Wheatstone bridge relation of resistances then exists in the lengths of the wire, $X:Y::E:F$. And since these resistances are along uniform wires the same relations exist between *lengths* as between *resistances*. Consequently *E* can be read off directly in the terms of *X* if the lengths *A D* and *C D* are laid off numerically equal to *A K* and *C K*.

The foregoing method involves no computation. It is evident from the above proportion that if the entire length of resistance wire were made some even number of any convenient unit (say sixteenths of an inch) that a substitution of values in the proportion would give the distances. For example, if the resistance wire had a length of 1,000 and balance were found at 432 from the end to which the faulty conductor was attached, the distance to the fault would be 432/1,000 of the *entire* length of the conductors, or 432/1,000×2 of the length of the *cable* from the testing point.

By this method, involving simple computations, the same wire stretched on a convenient board may be used for all measurements. It becomes in effect an ohmmeter.

If more than one faulty place exists in the conductor, the test will give approximately the mean position. So, having made the test and cut the cable at the indicated place, test both ways to ascertain if both parts are not defective. If sound toward either station, the fault should be relocated in the defective part.

It will probably be found near the position of the first cut and, having allowed a reasonable percentage error, on the second cut it is highly probable the faulty section will be cut off. It has been found that generally the error of determination will fall within 1 per cent.

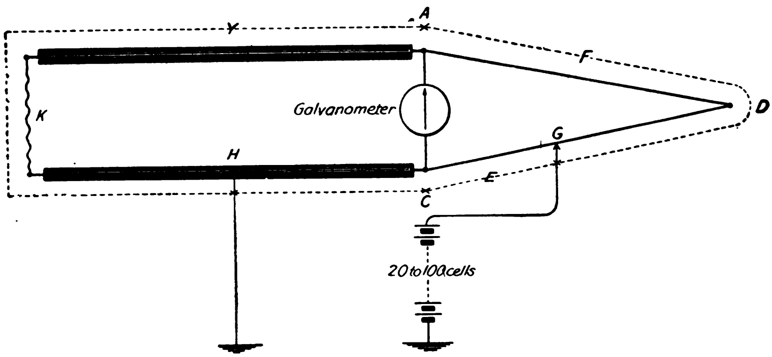


Fig. 9–3.—TEST, LOCATION OF FAULTS WITH IMPROVISED APPARATUS, USING A GALVANOMETER.

A word may be said regarding the telephone receiver as a detector of feeble currents. It is much more sensitive than the average pivoted galvanometer and will stand infinitely more abuse. However, in noisy places the galvanometer may be substituted for the telephone in this test.

If the fault has a high resistance, so that the four or five cells of battery perimssible in the manner of connecting shown in diagram can not send sufficient current through, then some form of rather sensitive galvanometer becomes necessary with the increased battery and change of connections required. In place of the battery in figure 9–2, connect the galvanometer. In place of the telephone receiver, connect a battery of from 20 to 100 cells in series. Then proceed as with the telephone receiver, noting that for each break or irregularity of contact of the searcher wire there may be a kick of the galvanometer, due to capacity or inductance, and that balance is obtained only when the galvanometer shows no deflection when the searcher wire is at rest. (Fig. 9–3.)

A fault in a single conductor cable, or one involving *all* the conductors of a multiple cable, may be located if two additional wires of sound insulation between the points connected by the faulty cable are available.

As the lengths and resistances of these wires are immaterial, temporary or roundabout wires may be utilized.

The method of procedure is as follows: Stretch a single piece of resistance wire *A B* (figures 9–4 and 9–5) whose length is some even number of parts, say 1,000 sixteenths of an inch. The two sound outside wires *I* and *K* and the defective one *L* are connected at the distant end. The galvanometer, battery, and searcher are connected, as shown in figure 9–4, and the point of balance obtained. Call the reading *A* from the point *C*.

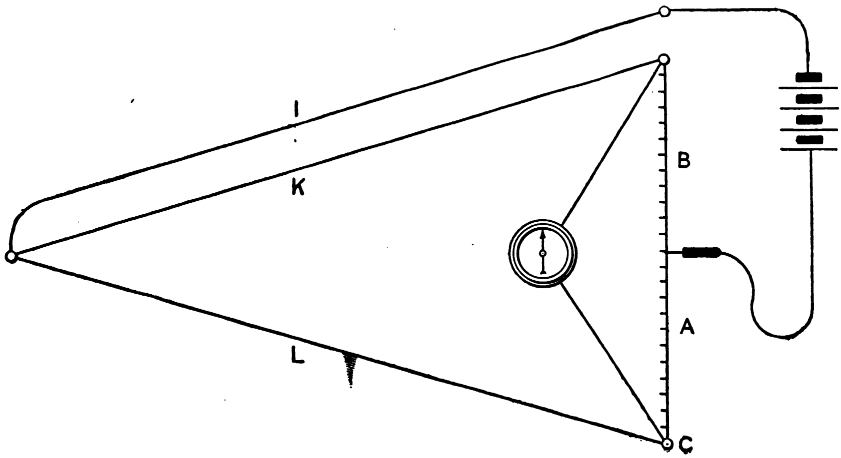


Fig. 9–4.—TEST, LOCATION OF FAULTS WITH IMPROVISED APPARATUS, ALL CONDUCTORS FAULTY.

Then connect up as in figure 9–5, joining the battery to earth or to the cable sheath. If the fault appears as a leak between two adjacent wires of the multiple cable, the lower end of the battery should be joined to the other faulty wire instead of the cable sheath or ground.

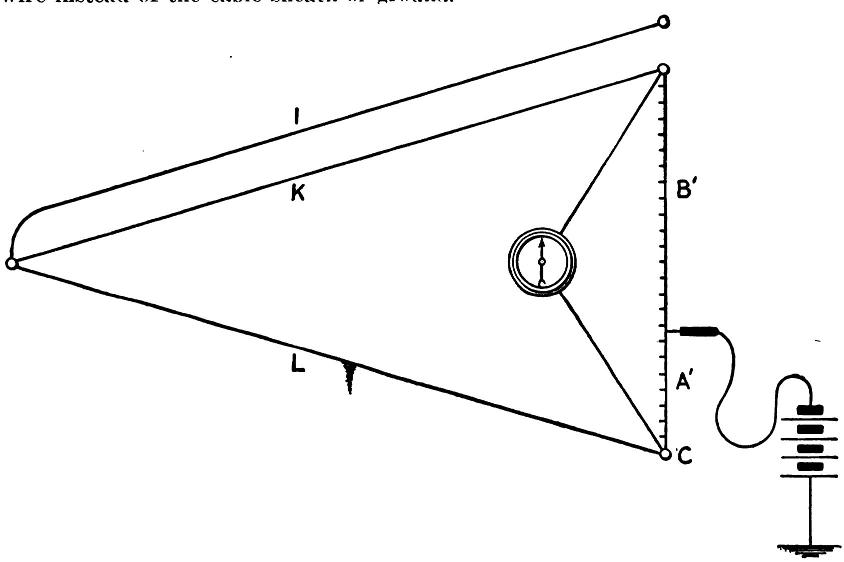


Fig. 9–5.—TEST, LOCATION OF FAULTS WITH IMPROVISED APPARATUS, ALL CONDUCTORS FAULTY.

When balance is obtained, note the reading on the resistance wire from point C. Call it A'. Then if length of faulty conductor is L feet, the distance of the fault from C is $\frac{A' L}{A}$ feet.

This method is particularly applicable to paper cables where a leak has made the insulation of all the conductors faulty.

Location of break in conductor.—The method applicable when the wire is broken inside the insulation, leaving the latter intact, is given below. This is the character of the fault generally produced when a conductor parts in a paper-insulation cable. Owing to the small capacity of this kind of cable the method is useful because of the practical difficulty in getting correct capacity values by galvanometer methods in small lengths of this cable.

The connections for the test are the same as that described in figure 9–3, except the telephone receiver is used in place of the galvanometer. The point H, instead of representing a fault in insulation, in this case represents the location of a break in the wire. It is best to use quite a number of cells, say 20 or 30, if available. The battery circuit is reversed and interrupted rapidly while a point is sought with the searcher along the resistance wire where the clicks are no longer heard in the receiver. When this point of balance is reached the distance to the break is then read off on the scale along the resistance wire from C to the point G, as explained in locating insulation faults. In this case the point G is in the corresponding position on the upper wire. The reason for this is that this wire having the greater capacity is charged through the bridge arm having the lower resistance.

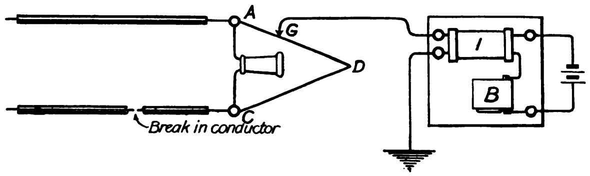


Fig. 9–6.—TEST, LOCATION OF FAULTS WITH IMPROVISED APPARATUS, CONDUCTOR PARTED.

In the last-named test an interrupted current of rather high voltage is required. A method of getting this with only two dry cells is to take a local battery telephone induction coil (I in the figure) and attach it to a wooden base, together with an ordinary small metal buzzer "B."

The connections are as shown in figure 9–6. When the battery is connected the buzzer sends a vibratory current through the primary coil. A vibratory current of much higher voltage is induced in the secondary, and this is utilized in place of the battery currents, as shown in the foregoing tests.

THE VOLTMETER AND AMMETER.

On land telegraph lines and the apparatus connected therewith the electrical units with which we are usually concerned in measurements and tests are those given in Ohm's law—the current in amperes equals the electromotive force in volts divided by the resistance of the circuit in ohms; expressed algebraically, $I=\frac{E}{R}$. The galvanometer, in one or the other of its forms, measures current. When of low resistance and graduated properly, it is called an amperemeter or ammeter. When of high resistance, since the current flowing through it is practically independent of the relatively small variations of outside resistance, the galvanometer readings are directly proportional to the electromotive force *E*. And when properly graduated it becomes a voltmeter. The ammeter and voltmeter, on account of portability and quickness and accuracy with which read-

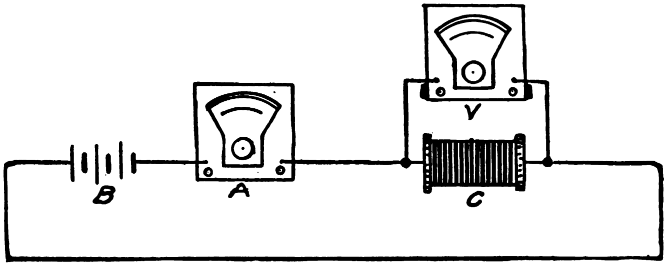


Fig. 9–7.—TEST, MEASURING OHMIC RESISTANCE BY MEANS OF VOLTMETER AND MILLIAMMETER.

ings are taken, are very satisfactory instruments for telegraph testing. It is evident if I and E are measured by an ammeter and voltmeter, respectively, that R becomes known—for according to Ohm's law $R=\frac{E}{I}$. For example, if we connect the ammeter A, battery B, and a resistance coil C together, as in figure 9–7, we may read the current flowing. The small current commonly used in telegraphy is conveniently expressed in milliamperes, and the ammeter graduated for these is called the milli- or mil-ammeter. If we attach a voltmeter V to the terminals of the resistance coil C, it will give the difference of potential (E. M. F.) produced at these two points by the current flowing between them.

Suppose the milliammeter reads 28 milliamperes (0.028 ampere) and the voltmeter 4.23 volts. Substituting in $R=\frac{E}{I}$, $R=\frac{4.23}{.028}=151$ ohms. The general rule in connecting up the ammeter and voltmeter for such measurements is to put the ammeter in the circuit, and the voltmeter shunting the part of the circuit whose resistance is desired. The practical use of the instruments in testing telegraph lines is given below.

The theoretical connections are shown in figure 9–8, the voltmeter being connected in shunt to line and ground, and the milliammeter in series in the circuit.

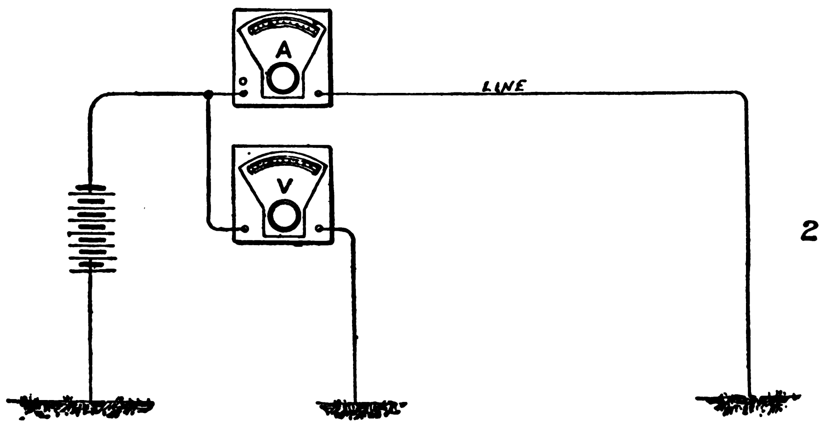


Fig. 9–8.—TEST, MEASURING OHMIC RESISTANCE OF TELEGRAPH LINE BY MEANS OF VOLTMETER AND MILLIAMMETER.

The correspondence of this with figure 9–7 will be noted. The practical connections are shown in figure 9–9.

A portable voltmeter reading to 200 volts (V), and milliammeter reading to 150 milliamperes (A), are mounted on a board and connected with the regular switchboard cord and wedge, as shown, the other terminal of the voltmeter being connected with the ground.

When the wedge is inserted in any line spring jack, the ammeter is connected in the circuit and the voltmeter shunted to the ground, as shown in figure 9–9. The deflections of the ammeter and the voltmeter thus give I and E in the formula $R = \frac{E}{I}$ and the resistance becomes known.

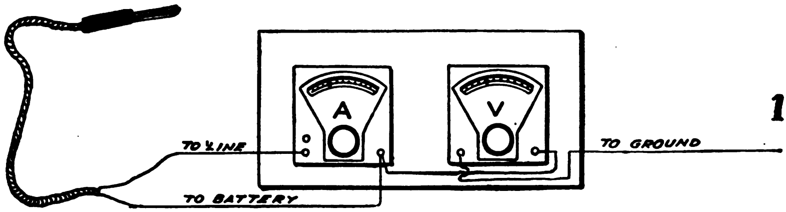


Fig. 9–9.—TEST, MEASURING OHMIC RESISTANCE OF TELEGRAPH LINE BY MEANS OF VOLTMETER AND MILLIAMMETER, PRACTICAL CONNECTIONS.

To test, cut off battery at most distant station, ground line, and take readings. Now open the key for a few seconds and take a second set of readings. Repeat this process with all stations up to the nearest one. The readings with stations grounded give resistance of line (including relay) to each, while readings with the keys opened would give the insulation resistance to each.

The following shows some methods of using the voltmeter alone for various measurements when the ammeter is not available:

THE VOLTMETER (0–5, 0–150 VOLTS PATTERN).

This instrument is a galvanometer of the D'Arsonval class, in which a pivoted coil, controlled by a spiral spring turning in jeweled bearings, carries a light aluminum pointer moving over an equally divided scale.

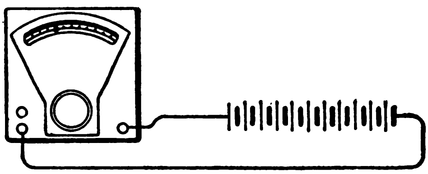


Fig. 9–10.—TEST, WITH VOLTMETER, VOLTAGE OF A BATTERY.

This coil turns, when a current passes through it, in the strong field between the poles of a powerful permanent magnet. In the base are two resistance coils, one or the other of which is always in series with the movable coil, depending upon which scale is used—the 150 or 5 volt scale.

Caution.—To prevent bending the pointer by violent action, always test first with the 150-volt scale. If the pointer indicates less than 5 volts, use the other binding post and take advantage of the greater accuracy of the 5-volt scale.

TO TEST THE VOLTAGE OF A BATTERY OF A NUMBER OF CELLS.

Use the 150-volt scale and connect up as shown (fig. 9–10).

For not more than 3 sal ammoniac, 4 bluestone, or 2 storage cells in series use the 5-volt scale.

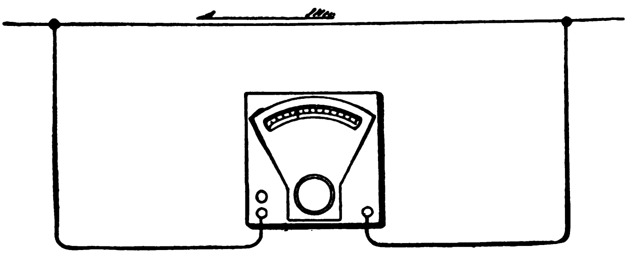


Fig. 9–11.—TEST, WITH VOLTMETER, DIFFERENCE OF POTENTIAL BETWEEN TWO POINTS ON WIRE.

TO MEASURE THE DIFFERENCE OF POTENTIAL (PRESSURE) BETWEEN ANY TWO POINTS OF A WIRE OR EXTREMITIES OF A COIL CARRYING A CURRENT.

The connections indicated in figures 9–11 and 9–12 would give the differences of potential at the two points on the wire, or at the extremities of the coil, respectively.

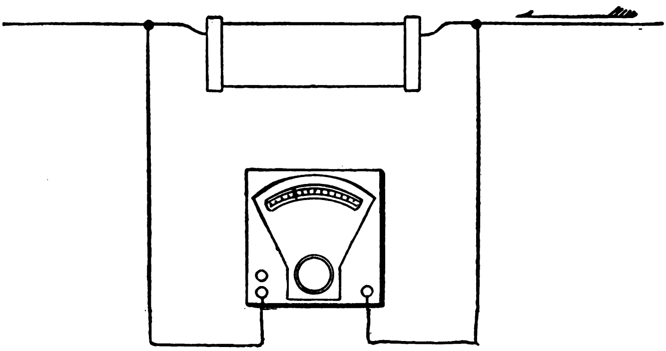


Fig. 9–12.—TEST, WITH VOLTMETER, DIFFERENCE OF POTENTIAL AT EXTREMITIES OF A COIL.

TO MEASURE A RESISTANCE.

To measure a resistance less than 3,000 ohms use two or three dry or Gonda cells in series, get their voltage, using the 5-volt scale. Call this V. Then connect up with the unknown resistance X (fig. 9–13), as shown, and call this scale reading V'.

The resistance of the volmeter, using 5-volt scale, is given in the sliding cover of box. Call this R.

Then

$$X = \frac{R(V-V')}{V'}.$$

This is very inaccurate for resistances of only a few ohms unless the resistance of the battery is taken into account.

In measuring resistances from 3,000 to 250,000 ohms use the 150 scale, noting the value of R given on the cover for this. The same connections and formula are applicable.

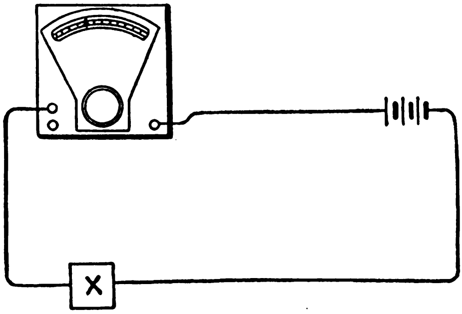


Fig. 9–13.—TEST, WITH VOLTMETER, TO MEASURE OHMIC RESISTANCE.

To secure greater accuracy in either of above cases, the battery should have sufficient E M F to bring the value of V as near 5 or 150 as practicable.

Example.—(1) Using 5-volt scale. Resistance to be measured (X) is an ordinary telegraph relay magnet.

Suppose $R=520$. Three cells dry battery in series give $V=4.35$ volts. When X is connected in, $V'=3.40$.

Then

$$X=\frac{520\ (4.35-3.40)}{3.40}=145.29 \text{ ohms.}$$

(2) Using 150-volt scale. Determine the insulation resistance of 110-volt storage battery (leakage from either pole of battery, or its connections, to earth).

Suppose R for this scale=15,500 ohms. Voltage across terminals, $V=110$ volts; voltage between one of the terminals and earth (V')=12 volts.

$$X=\frac{15{,}500\ (110-12)}{12}=126{,}583 \text{ ohms.}$$

This would indicate a slight leak, probably at or near the negative end of battery if the tests were made at the positive terminal.

If some coils of known resistance are available, resistances can be measured more accurately as follows:

The known coil and the resistance to be measured, marked respectively r and x, are connected with each other and a battery, as shown (fig. 9–14). The voltmeter is connected first as indicated by the full and then as by the broken lines. If the voltage indicated in the first case is E and in the second it is E',

$$E:E' :: r:x. \quad \therefore x=\frac{E'r}{E}.$$

Use enough battery to make a good readable deflection, and if several known coils are available use the one which is somewhere near the resistance to be measured.

Example.—Known coil, 10 ohms. Voltmeter shunting this gave 3.2 volts, and shunting the unknown gave 4.7 volts. Hence

$$x=\frac{4.7\times10}{3.2}=14.7 \text{ ohms.}$$

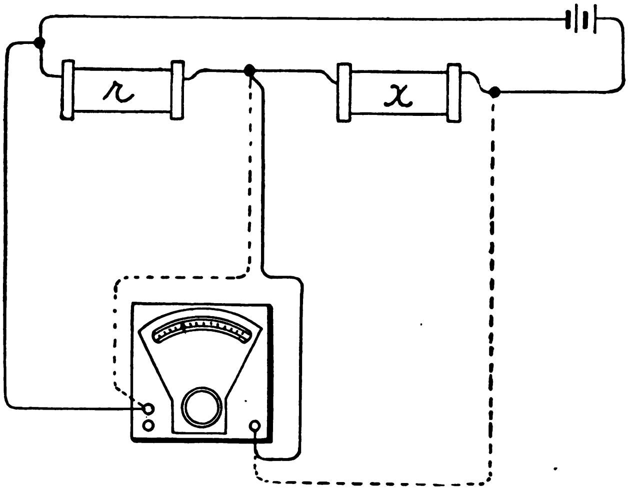


Fig. 9-14.—TEST, WITH VOLTMETER, TO MEASURE OHMIC RESISTANCE, USING A KNOWN RESISTANCE.

TO MEASURE CURRENT WITH THE VOLTMETER.

If we know the resistance of a wire or coil, and have a steady current flowing through it, the voltmeter wires applied at the terminals of the wire or coil will give a certain deflection, E. Hence, since $I=\frac{E}{R}$, if we substitute for E and R the known values we get I. (Connections shown in figs. 9–11 and 9–12.)

Example.—A certain current is flowing through a 4-ohm telegraph sounder. When the wires from the voltmeter (5-volt scale) are connected at sounder binding posts, the voltmeter indicates 0.8 volt.

Substituting as above,

$$I=\frac{.8}{4}=.2 \text{ ampere.}$$

TO MEASURE THE INTERNAL RESISTANCE OF A BATTERY.

Using the 5-volt scale, first take the voltage of the cell. Then take the voltage at the terminals of a coil of rather low resistance (a 4-ohm sounder, for instance), in circuit with the cell (fig. 9–12), being careful not to close battery circuit until ready to read the voltmeter. Multiply the voltage of the cell by the resistance of the coil and divide by the voltage at terminals of coil. From the result subtract the resistance of the coil. The remainder is the internal resistance sought.

Example.—The voltage of a dry cell is 1.41, and the voltage at terminals of 4-ohm sounder in circuit with the cell is 1.24.

$$1.41\times 4\div 1.24=4.5.$$

4.5—4=.5 ohm, internal resistance of cell. Care must be taken to read voltmeter quickly after closing the circuit through coil, or the result will be vitiated by the polarization of the cell.

The internal resistance of a dry cell can also be determined by the use of the voltammeter previously described. The method of procedure in this test is as follows;

Never connect with more than one storage cell or more than three of other kinds. Too large a current or high voltage will bend the indicator or burn out the coils.

Dry batteries and sal-ammoniac batteries (such as Leclanche, Gonda, etc.) should have voltages between 1.4 and 1.5. This is obtained by connecting with binding posts *V*, *P* being positive. Then, by connecting with *A* instead of *V*, the current is indicated on the ampere scale. Since the resistance of the ampere coils is 0.5 ohm, the internal resistance of the cell is given by the formula $\frac{E-0.5I}{C}$ where E=voltage of the cell and I=current in amperes. The deterioration of a dry or sal-ammoniac battery is shown by a fall in voltage much below 1.4 and a rise in its internal resistance. This latter should not exceed a few ohms.

The voltage of a bluestone cell is ordinarily about 1. Its internal resistance after it is in good working order should not exceed 3 ohms.

The voltage of a storage cell varies between 1.8 when about discharged to 2.5 when being charged fully. After charge it is about 2. The internal resistance should be very small.

Edison primary type V and Gordon cells have about 0.75 volt E. M. F. and internal resistances from .06 to .25 ohm.

Fuller cells (with electropoion fluid) have from 1.8 to 2 volts E. M. F. and an internal resistance varying from one-fourth to one-half ohm. A table of internal resistances should be made out for the class of batteries to be tested to save computations in making the round of inspections.

In this connection the following table of internal resistance is supplied:

Type of cell.	Ohms.	Type of cell.	Ohms.
4–0 dry	0.25	Leclanche and Gonda	1.50
4 dry	.25	Samson	.25
5 dry	.20	Gravity	3.00
6 dry	.20	Edison primary type V and Gordon	.10
7 dry	.12	Storage cell	.005
8 dry	.10	Fuller	.25

THE WHEATSTONE BRIDGE.

This has long maintained its position as the best means for measuring resistances, and in one or the other of its various forms can be used for a great range of measurements.

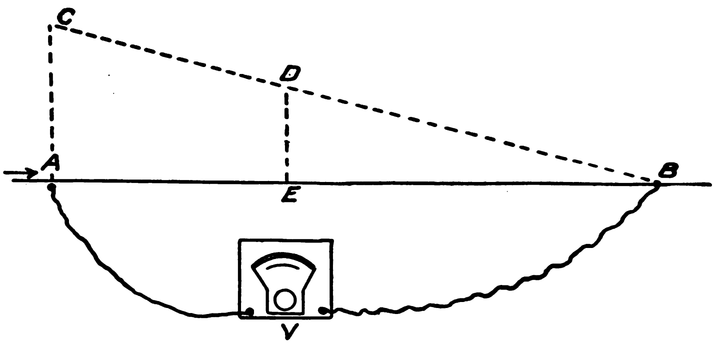


Fig. 9–15.—TEST, OHMIC RESISTANCE, FALL OF POTENTIAL.

The "fall-of-potential" principle is applied, which may be illustrated as follows (fig. 9–15):

If a current is flowing along a wire in the direction of *A B*, and the terminals of a voltmeter *V* are applied at *A* and *B*, a certain potential difference between these points will be indicated; that is, there will be a fall of potential from *A* to *B*, which will be uniform if the wire is of uniform resistance. This may be represented graphically, for if the height of *A C* represents the total difference of potential, and the line *C B* represents the fall of this to *B* along the uniform wire, then at any point, say at *E*, the height *D E* will represent the potential difference between *B* and *E*, which is proportional to the length of wire or resistance remaining.

If we take a circuit divided at *A* (fig. 9–16), the fall of potential along the wire *A E B* is equal to that along the wire *A G′ B*, and having passed over a certain proportion of the total resistance *A E B* we reach a point *E* which will be of the same potential as some point *G′*, of *A G′ B*. If *E* and *G′* be connected through a galvanometer no current will flow through the galvanometer. It can be proven that when the resistances of the divided circuit bear the proportion—*A E:A G′: :E B:G′ B*—the points *E* and *G′* are at the same potential with respect to each other, and the galvanometer will not be deflected.

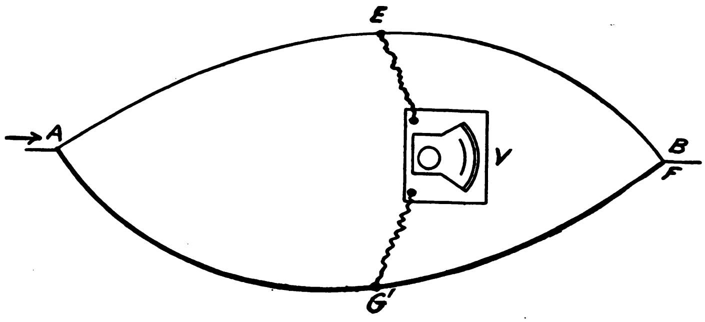


Fig. 9–16.—TEST, PRINCIPLE EMPLOYED IN WHEATSTONE BRIDGE.

The relation of parts in the conventional diagram of the Wheatstone bridge (fig. 9–17) will now be apparent. If the resistance in the coils of *A* and *B* are equal or bear any other simple numerical relation, then the same numerical relation exists between *R* and *X*, and if *R* be a box of known resistance coils, *X*, the unknown resistance, becomes known from the above-stated relation *A: B: : R: X*.

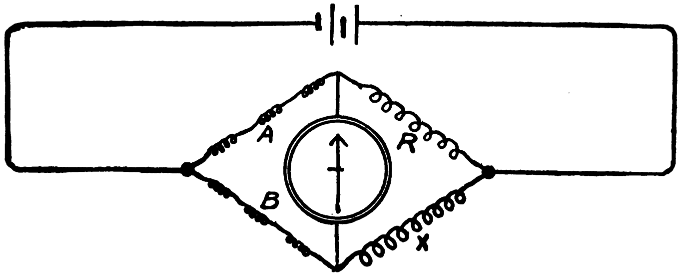


Fig. 9–17.—TEST, WHEATSTONE BRIDGE, CONVENTIONAL DIAGRAM.

If we straighten out *A* and *B* and bend up *R* into compact form, insert keys into the galvanometer and battery circuits, we shall have the diagram of the ordinary or "post-office" form of the bridge (fig. 9–18). The resistance in the "balance arm" *A* and *B*, and in *R* are short-circuited by inserting the plugs, and they are introduced by withdrawing the plugs. The galvanometer now most usually employed is some sensitive form of the suspended-coil type.

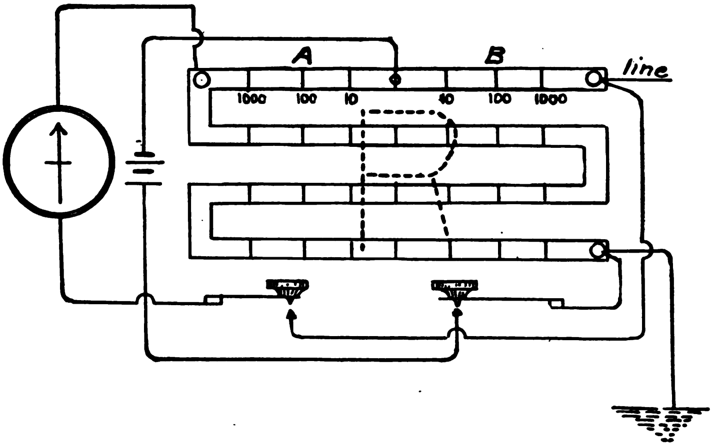


Fig. 9–18.—TEST, WHEATSTONE BRIDGE, CIRCUITS, DIAGRAMMATIC.

The simplest measurement is made with *A* and *B* equal. Start out with, say, *A* and *B* 100 ohms each. Then connect up the terminals of the unknown resistance *X* ("*line*" and "*ground*"), and closing the battery key, tap the galvanometer key. There being no resistance unplugged in *R*, the galvanometer needle will be deflected to the side indicating "too small" for *R*. Now unplug in *R* and test until the right amount is unplugged in *R* to get a balance or no deflection, then, since $A=B$, $R=X$. If fractional ohms are to be obtained, *A* must be 10 or 100 times greater than *B;* then *R* is 10 or 100 times greater than

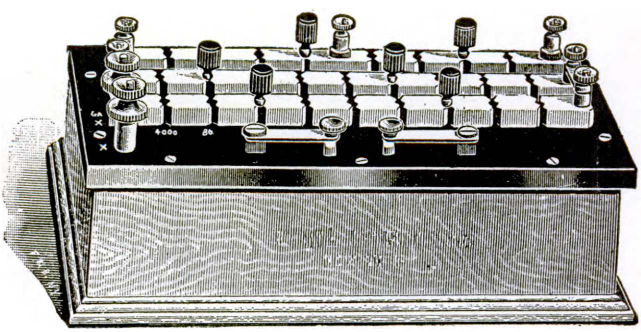


Fig. 9–19.—TEST, WHEATSTONE BRIDGE, POST-OFFICE FORM.

X. Likewise, if *X* is greater than can be obtained by unplugging in *R*, then make *B* the greater and it reverses the multiplier. Practice and care are requisite to obtain accurate results. Always close battery key before galvanometer key and open galvanometer key first.

In measuring resistances of a telegraph line be certain all line batteries are disconnected before making the measurement. The line is connected with one of the *X* binding posts, the ground to the other. (See fig. 9–18.)

Many modifications of this form of bridge are in use. Some are arranged so the plugs are inserted at the points where the introduction of resistance marked is desired.

One of the familiar forms in which the bridge is made for laboratory use is shown in figure 9–19. In this the resistances are introduced by taking out plugs. The further row of strips are for the *A* and *B* arms, the other rows constituting the *R* arm. The keys are for introducing battery and galvanometer into circuit.

The following graphical demonstration of the stated proportionality of the resistances in the four arms of the Wheatstone bridge when balance is obtained is of interest in connection with the foregoing:

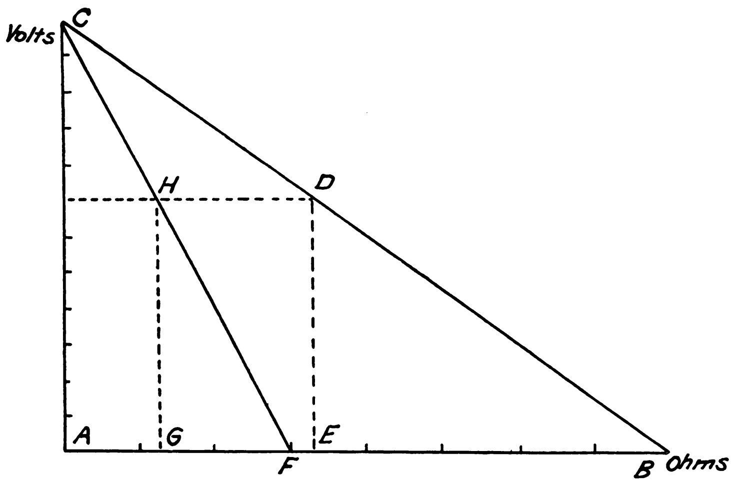


Fig. 9–20.—TEST, WHEATSTONE BRIDGE, GRAPHICAL DEMONSTRATION.

Lay off *A B* to represent the resistance in the upper branch of the bridge (fig. 9–20) and *A F* to represent resistances in the lower. Let *A C* represent the difference in potential between the two ends of the bridge, and draw lines *C B* and *C F*. These are the "fall of potential" lines along the upper and lower branches respectively.

A horizontal line *H D* touches points *H* and *D* at the same potential. These projected on lower lines represent the points of galvanometer connection. The resistances passed over in lower and upper branches to reach these points of equal potential, measured on the lower line, are *A G* and *A E*.

Similar triangles give these proportions:

$$CD : DB :: AE : EB$$
$$CH : HF :: AG : GF$$
$$CD : DB :: CH : HF$$
$$AE : EB :: AG : GF$$
$$AE : AG :: EB : GF$$

F and *B* being at the same point in the conventional diagram of the bridge (fig. 9–16), the last proportion will be seen to be identical with that accompanying that figure.

The wide range of resistances that can be measured with a Wheatstone bridge has caused it to be likened to a pair of scales which may be converted from hay scales to a chemical balance. It has been noted that when the "balance arms" are equal the resistances of standard coils and measured resistances are equal; and by changing the ratio of these balance arms, which correspond to shifting the fulcrum in the steelyard, the standard resistance may be made to bear any desired ratio to the measured resistance.

VOLTAMMETER, PORTABLE.

Figure 9–21 shows the Weston model 280 voltammeter which is issued by the Signal Corps. The instrument is furnished in a neat leather case with carrying strap and is triple range, both as an ammeter and as a voltmeter. The scale reading as an ammeter being 0–3, 0–15, and 0–30, the scale readings as a voltmeter are 0–3, 0–15, and 0–150. One binding post is common for both ammeter and voltmeter connection, and the various scale connections are obtained by connecting other lead to proper one of six other binding posts mounted on base of instrument. All binding posts are appropriately marked.

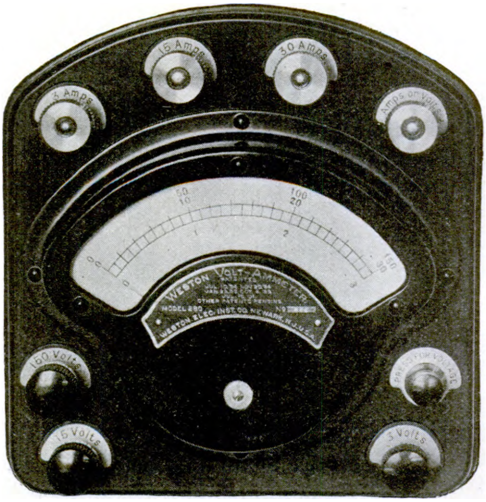


Fig. 9–21.—VOLTAMMETER, PORTABLE.

METHOD OF LOCATING FAULTS IN MULTIPLE CONDUCTOR CABLES WITH MODEL 1904 OHMMETER.

Arrange to have the distant end of the faulty conductor connected to a sound conductor in the same cable. Attach the faulty conductor to post X_1 on the ohmmeter and the sound conductor to post Q. See that the variable plug is not inserted at either 10 or 100. Attach a ground wire to X_2. Find a balance as in testing for copper resistance. If the reading, in scale parts, is A and the length of the cable, in feet, is L, the distance to the fault will be L multiplied by $2A$ divided by 1,000. These values hold for any size cable but assume that the conductors used are of the same gauge. The connections are shown in figure 9–22.

The following example will indicate the method of making this test:

Suppose connections have been made as above and the stylus is at 150 on the scale when a balance has been obtained. Suppose the cable to be 6,000 feet long; 6,000 multiplied by 300 will equal 1,800,000, which divided by 1,000 equals 1,800 feet, the distance from the observer to the fault.

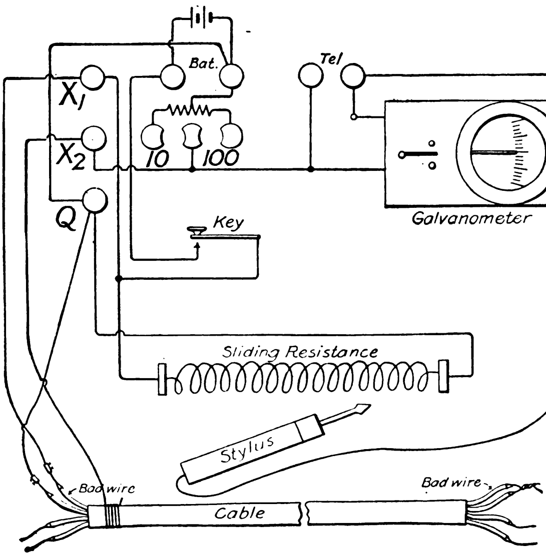


Fig. 9-22.—TEST, OHMMETER, LOCATION OF GROUNDS.

LOCATION OF A CROSS BY MEANS OF THE VOLTMETER.

In general the resistance of the wire to the cross and through the point of contact (the cross) of the two wires is small compared with the resistance of the voltmeter itself. The following method depends upon the approximate correctness of this assumption. The connections are shown in figure 9–23.

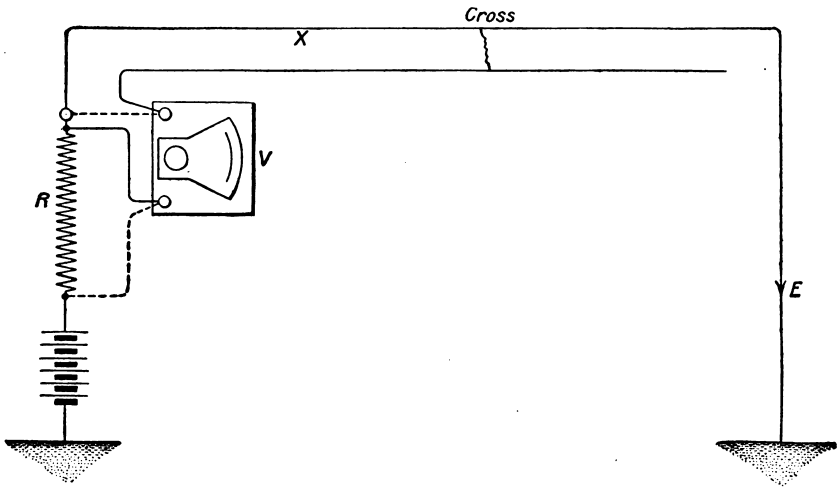


Fig. 9–23.—TEST, VOLTMETER, LOCATION OF CROSSES.

One of the wires is grounded at some station E beyond the cross, the other being opened there. The line battery being connected up through a known resistance, R (a 150-ohm relay, for instance), as shown, readings are taken of the voltmeter V connected as shown first by the full lines and second as shown by dotted lines.

Calling the first reading V^1 and the second V^2 and R 150 ohms, the resistance of the wire X to the cross is given by the formula $X=\frac{V^1}{V^2}\times R$; and if the resistance of the wire per mile is A ohms, the number of miles to the cross is given by $\frac{X}{A}$.

The quick readings that can be made with the voltmeter make this a useful method of locating swinging crosses.

The importance in all these tests, excepting ohmmeter, model 1904, of having some standard known resistances available is apparent. Spare relays and sounders, if not already measured up accurately, should be so measured up and marked at the first opportunity or request made for such standardized coils. So-called 150-ohm relays and 4-ohm sounders frequently vary 5 per cent from their stated resistance and would make considerable error in the calculated positions of faults if used as standards.

EXPLORING COIL.

It is oftentimes necessary to locate a ground or cross in cables installed in trenches or underground conduit where standard instruments are not available. The use of an exploring coil in such cases may avoid the necessity of taking up considerable lengths of cable and opening unnecessary test points.

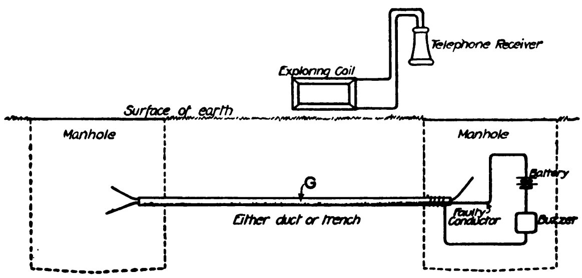


Fig. 9–24.—TEST, EXPLORING COIL, LOCATION OF GROUND.

The exploring coil may be made as follows: Take a 1-inch thick pine board of rectangular shape, 1 foot by 2 feet, and wind around its outer edge as many turns of insulated wire as convenient. This wire may be cotton-covered magnet wire, No. 18 gauge, or smaller. In place of this board a rectangular frame, with channel cross sections, may be made. To use the exploring coil, a source of alternating or pulsating current is applied to the grounded conductor. This source may be from a buzzer and induction coil connected to a battery of dry cells, a 30-volt telephone storage battery, or a 110-volt power circuit. The exploring coil, with terminals connected to a telephone receiver, is now carried along the route of the cable, being held as near the ground as possible with the plane of the coil parallel with the cable and the long side of the coil next to the ground. The buzzer should be heard in the telephone receiver until the grounded point in the cable has been passed, when the sound should cease entirely or become much weaker. The exploring coil may also be used for identifying cables where a number of them are laid in a common trench. A variable current is sent through the cable to be identified and is picked up by the exploring coil, one side of which should be held close to or parallel with the cable. The short end of the coil may be used for this purpose.

MURRAY AND VARLEY LOOP TESTS.

The preceding sections of this chapter have described certain methods of testing, entirely qualitative in character, as well as standard methods for measuring conductor resistance, electrostatic capacity, and insulation resistance. In addition to these there are certain quantitative measurements necessary for the location of faults in conductors, which will now be briefly described.

These tests for fault location consist essentially of cases of the application of the simple methods of measurements previously described, requiring special connections and a certain amount of computation from observations. It should be especially noted, however, that the methods of fault location commonly used do not necessitate special and complicated apparatus, but rather the application

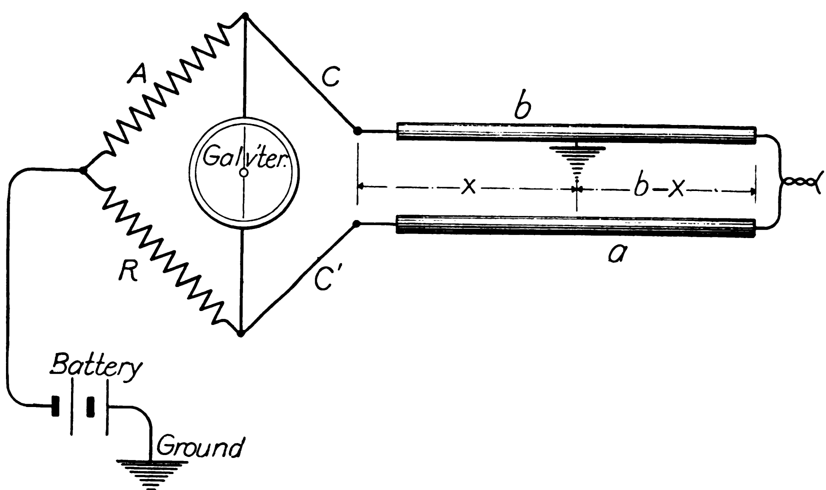


Fig. 9–25.—TEST, MURRAY LOOP, LOCATION OF GROUNDS.

of simple methods to special circuits and the solution of elementary formulæ. Two tests most generally used and of wide application are the Murray loop test and the Varley loop test. The Murray loop test is the more easily made, but is of less general application than the Varley.

The Murray loop circuit is shown in figure 9–25, in which A is one of the arms of a Wheatstone bridge and R the adjustable resistance. G is a galvanometer or other current indicater, C C' the leads from bridge to conductors under test, b the faulty wire, a a good wire of the same length and resistance. The resistance of the faulty conductor, from the point of test to the fault is denoted as x; a and b are connected at distant end as shown ,the leads C C' should be carefully measured, if their length and resistance are not negligible as compared with those of the wires a and b and the values recorded for use in correcting readings. When the resistance R is so adjusted that the galvanometer is not deflected the distance to the fault is—

$$x=\frac{A\,L}{A+R}$$

where L is the combined length of a and b. The above formula assumes that the leads are negligible. If such is not the case, the formula becomes—

$$x=\frac{A(L+C\,C')}{A+R}-C.$$

It will usually be practicable to make the leads negligible or at least to have $C=C'$. It is to be particularly noted that this method assumes that the good and bad wires are of equal resistance. It is advisable in each case to

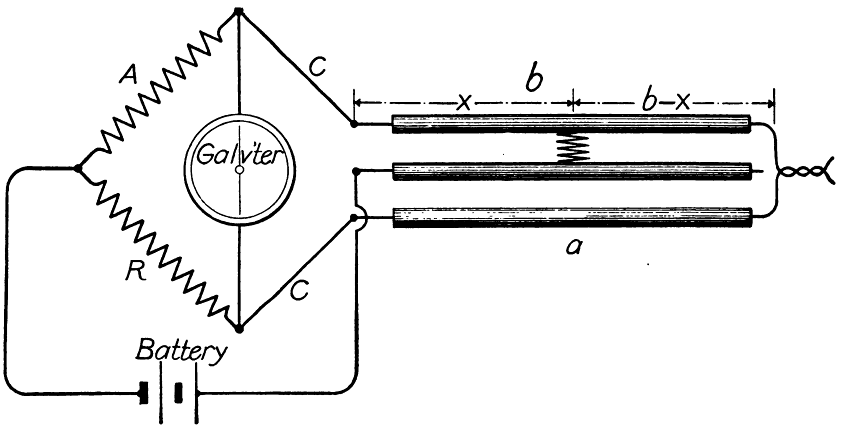


Fig. 9–26.—TEST, MURRAY LOOP, LOCATION OF CROSSES.

check the fault location obtained by the above circuit by reversing the wires a and b and making a second location. In the above formula A and R are in ohms, all other quantities in units of length.

For locating crossed wires the circuit of figure 9–26 should be used. It will be noted that the connections are the same as for locating grounds, except that the battery is connected to one of the pair of crossed wires.

The Varley loop test, while not so simple and quickly made as the Murray test described above, is of more general application and can be made in situations where the Murray test can not. The connections for this test are shown in figure 9–27. The various parts of the circuit are given the same letter designations as for the Murray test of figures 9–25 and 9–26.

With the circuit of figure 9–27 adjust the variable resistance arm R of the Wheatstone bridge until the galvanometer is not deflected, record the values of A, B, and R. Now disconnect the ground from battery and connect as shown by dotted line and measure the combined resistance of the leads C C' and the two conductors a b in series; call this value r. Combining the results of the two measurements taken above, the resistance of the conductor from the point of test to the fault is—

$$x=\frac{Br-A\,R}{A+B}-C.$$

Check the measurements and calculations obtained by the above process by reversing the connections of the bridge to the conductors at either end of the leads and obtain a second set of readings. If the new values of bridge

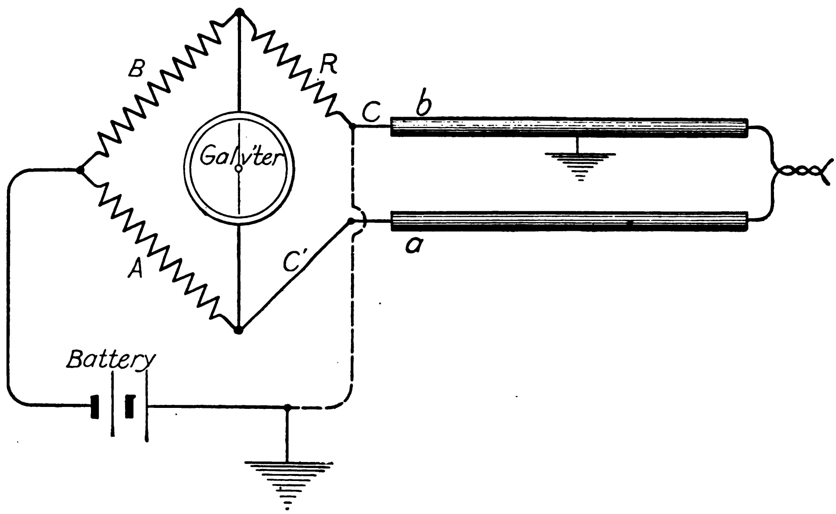


Fig. 9–27.—TEST, VARLEY LOOP, LOCATION OF GROUNDS.

readings be designated as A', B', and R', the new value of the resistance to the fault is—

$$x=\frac{A'(r+B')}{A'+B'}-C.$$

If C equal the total resistance of the bad wire the distance to the fault is $\frac{a}{C}L$, where L is the total length of the wire. The check measurements should always be made when using either the Varley or the Murray loop test, as the time and labor required are inconsiderable and the certainty of location is much increased.

For crossed wires the method of figure 9–28 should be used. The circuit, it will be noted, is the same as on figure 9–27, except that one wire of the crossed pair is used to replace the earth connection.

LOCATION OF FAULTS IN TELEGRAPH LINES.

" In order to secure the best possible result in the working of telegraph lines we must keep down the resistance of the conductor in the circuit and increase the resistance of the insulator to the greatest possible extent. In other words, the resistance must be as small as possible in the route we wish the electric current to travel and as great as possible in every other direction. The practical working value of a telegraph line is the margin between the joint resistance of the conductor and the insulator and that of the insulation alone. The tension of the retracting spring of the relay armature when upon a ' working adjustment ' is the measure of this margin or difference. It is evident that this margin may be increased in two ways, viz: (1) By increasing the insulation resistance; (2) by decreasing the resistance of the conductor."—Pope's Modern Practice of Electric Telegraph.

Faults causing departure from normal working conditions are due to partial or complete contacts of the line wire, directly or indirectly with the ground,

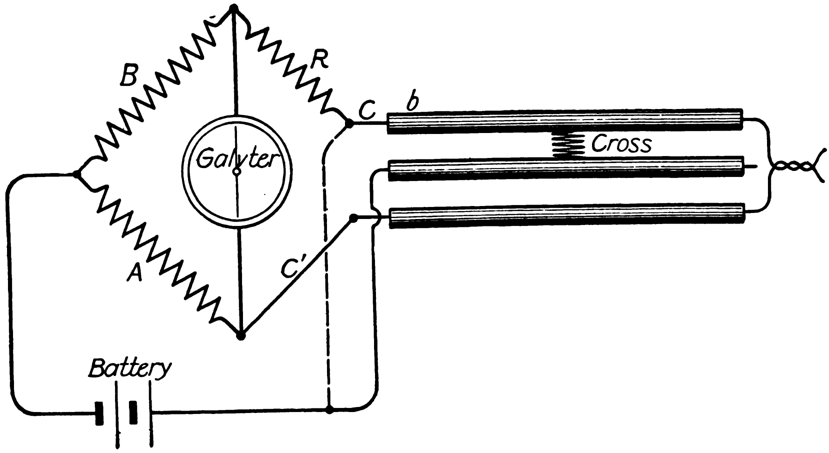


Fig. 9–28.—TEST, VARLEY LOOP, LOCATION OF CROSSES.

usually called by telegraphers "escapes" and "grounds"; crosses, caused by two or more wires coming together; and partial or complete disconnections, causing abnormally high resistance, or complete interruption.

"Escapes" mean imperfect insulation, due to defective insulators, contact of foliage with the wire, or defective office wiring. "Grounds" are often brought about by the wire being down on the ground, to its being detached from an insulator and lying against an iron pole, or defective office wiring.

Abnormally high resistance is due to defective and corroded joints in the line wire or to bad connections in the office wiring, instruments, batteries, or grounds.

When stations are not very far apart, especially where they are along a railroad or good road, the location of the fault between two stations by calling up each station in succession is usually sufficient.

In case of escapes it is evident that opening the key beyond the escape will not entirely open the circuit at the testing office where the main-line battery is located. So by opening in succession, beginning at distant stations, until we come to a station where practically all current ceases when the key is opened, will indicate that we have passed the escape.

The inability to work beyond a given station indicates a "dead ground."

Total breaks are located by stations successively grounding, beginning at the nearest office to the testing office.

High resistances due to imperfect connections are located by successive grounding in a similar way, a sudden marked falling off in strength of current indicating that the high resistance has just been passed.

In the case of crosses an intermediate office is asked to open No. 1 of the crossed wires and work on No. 2. If upon opening No. 2 at the testing office the cross remains, as shown by distant stations' sending coming in on No. 1, it is evident that the cross is between the testing office and the intermediate one. If the cross had disappeared upon opening No. 1 at the intermediate office it is beyond the intermediate office.

In the first case the office next nearest the testing office is called and the test repeated there. In the second case we should proceed outward from the intermediate office. A metallic cross may be distinguished from a leakage or "weather cross" by the sending through the cross in the first case coming nearly as strong as it does on its own wire.

If a high resistance fault is due to bad office connection it can be detected by cutting out the offices in succession until an evident improvement is noted in working. If due to bad joints in the line it can generally be detected by grounding at each station in succession; but these can best be located by measurements of resistances from point to point.

Faulty ground plates often introduce very large resistance in the line. Connections with these should be very carefully made. Only soldered joints should be permitted, if possible, and a good-sized rod, plate, or a good length of coiled wire buried in thoroughly damp ground should be used. It has often been found that the resistance of the ground connection was as much as all the rest of the circuit.

Two lines connected with a bad ground plate will behave as if crossed.

LOCATION OF CROSSES OR LEAKS IN TELEGRAPH LINES BY MEANS OF THE WIRE BRIDGE.

For crosses (see fig. 9–29): Call crossed lines No. 1 and No. 2. Request terminal station or any station beyond cross to open No. 1 and ground No. 2 as in diagram. The distance to this station is L miles. Connect to bridge consisting of a resistance wire stretched over a scale of 100 equal parts, galvanometer and battery as shown. Call divisions of wire when balance is obtained A and B. The distance to cross $X = \frac{B}{100}L$.

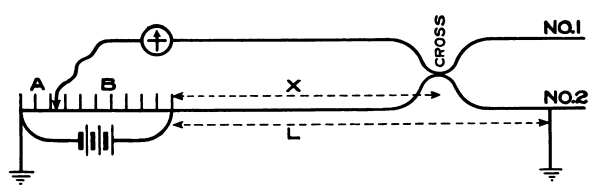


Fig. 9–29.—TEST, IMPROVISED BRIDGE, LOCATION OF CROSSES.

$$\text{Proof: } A:B::L-X:X$$
$$AX=BL-BX$$
$$X(A+B)=BL; \quad X=\frac{B}{A+B}L$$
$$A+B=100 \;\therefore\; X=\frac{B}{100}L$$

For leaks (see fig. 9–30): Suppose No. 1 has an escape (leak) at point indicated. Terminal or station beyond leak connects No. 1 and No. 2, and the connections are made as shown, for wires of same gauge and material.

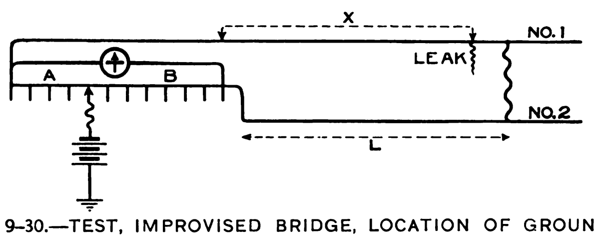


Fig. 9–30.—TEST, IMPROVISED BRIDGE, LOCATION OF GROUNDS.

Then if terminal station is L miles the distance to the leak X when balance is obtained is $\frac{A}{50}L$ miles.

$$\text{Proof: } A:B::X:L+(L-X)$$
$$2AL-AX=BX$$
$$X(A+B)=2AL;\quad X=\frac{2A}{A+B}L.$$
$$A+B=100 \qquad \therefore X=\frac{A}{50}L$$

Intermittent or swinging escapes, grounds, and crosses are exceedingly troublesome to locate. They often require accurate and prompt measurements. The Weston voltmeter and milammeter set described, being capable of almost instantaneous readings, is particularly useful in this kind of measurement. The ohmmeter measures resistances directly and almost as quickly. The Wheatstone bridge gives the most accurate results, but considerable skill and experience are necessary in its use.

The ohmmeter and Weston set will, it is believed, give greatest satisfaction in ordinary office measurements of resistance. The voltammeter has the additional advantage of giving means for measurements of voltage and current as well.

The ohmmeter furnishes not only a ready means of measuring resistance, but lends itself to loop tests as well.

Where only one wire connects the stations, grounds or escapes may be approximately located by the ammeter or voltmeter as previously stated.

No very satisfactory simple methods exist for locating escapes when only the faulty wire is available, and the tests can be made at one end only.

The simplest one is the Blavier test. This consists of making measurements of resistance, first with the distant end grounded and next with the distant end open. The resistance of the entire line, when in good condition, must be known. (See fig. 9–31.)

Suppose measurements are made from *A*, *B* is asked to open, and measurement is made from *A* through wire to fault and through fault. Call the resistance *M* ohms. *B* then closes and another measurement is made. Call this

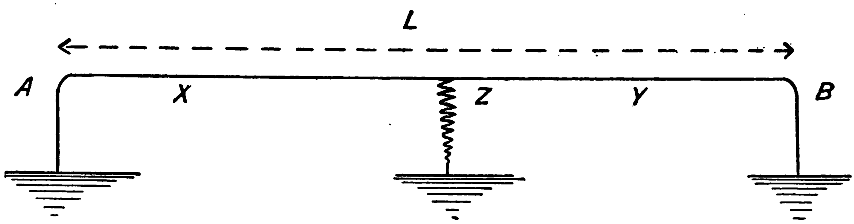


Fig. 9–31.—TEST, BLAVIER, LOCATION OF GROUNDS.

N ohms. If the resistance of the line is *L* when in good condition, the resistance in ohms *X* to the fault will then be given by the formula:

$$X=N-\sqrt{(L-N)\,(M-N)}.$$

A number of pairs of readings, using each end of the battery, if possible, should be made, and the mean of those pairs that agree most nearly should be taken.

The ohmmeter or Weston set may be used to advantage in these measurements and readings obtained as quickly as possible when the battery current is thrown on, as the resistance may vary rapidly, due to the polarization at the fault. It is an advantage to have the current through the escape Z the same when measuring M and N. As a rough compensation in land line measurement, use double the battery in measuring N as when M is measured.

FAULTFINDER.

An instrument termed by its manufacturer "Faultfinder" is issued in special instances by the Signal Corps.

The following is an extract from a catalogue relating to the faultfinder:

This instrument has been designed with a view of reducing to a minimum, calculations connected with fault location, also to simplify manipulation as much as possible. It may be used to measure conductor resistance, to measure fault resistance, to locate faults by four different tests, and when used with a buzzer and telephone, to locate opens.

Full directions concerning the use of this instrument are framed on the inside of cover. A special battery which is supported in bottom of case is necessary for its operation.

Figure 9–32 shows the faultfinder with cover raised.

Fig. 9–32.—FAULTFINDER.

LINES OF INFORMATION.

This general term has been adopted to apply to the means by which military messages are transmitted between two or more stations.

Under modern conditions lines of information are nearly always operated electrically. On account of its certainty, secrecy, and speed, telegraphy over wire lines is to-day without a rival for use on military as well as commercial lines.

As an army advances into conquered territory it will utilize as far as possible existing commercial lines to connect it with its base. If lines are constructed, they will generally at first consist of the insulated wires laid on the ground which follow the advance. Such of these as are needed will subsequently be put up as light lines on lances, afterward to be converted into permanent pole lines where necessary. Lines of a temporary character will be constructed or laid connecting the camps. When the army goes into action, an important series of lines are required connecting the commanding general, the corps, division, and brigade commanders, the artillery, and probably important points of observation and control at other places on the line.

Classified as to their construction, lines of information are permanent, semipermanent, or field lines.

Permanent lines are those similar in construction to the standard telegraph lines, and usually consist of heavy, bare copper or galvanized iron wire. No. 9 galvanized wire is the standard in our service. These wires are supported on substantial insulators and strong poles. Such lines are generally operated with the standard relays and sounders familiar in commercial offices.

Semipermanent lines consist of lighter bare wires, usually No. 14 galvanized, supported on lighter poles called lances, or on light tubular steel poles. These lances are fitted with hard rubber or composition insulators. Lines such as these were formerly the standard military construction, and telegraph trains, consisting of wire wagons, battery wagons, and lance trucks, could construct from 7 to 15 miles of these lines a day, depending on conditions. These lines were generally operated with box relays, but in modern use the telephone would frequently be the instrument employed.

Field lines are those laid hastily for temporary use, and usually consist of insulated wire paid out from reels on carts or wagons or in the smaller size wire from hand reels or wire carriers. Sometimes bare wire is used, in which case only the "buzzer" will operate satisfactorily over them. This buzzer is generally used on all field lines, although the field induction telegraph set may be substituted for it under some conditions.

Classified in regard to their use, lines of information may be considered as either strategical or tactical lines.

Strategical lines are usually of the permanent or semipermanent character, and may be part of the commercial system of the country. They are "base lines" in general, as they lie behind the advancing army and maintain communication with the base and thence to the seat of government. On account of their importance they would frequently be duplicated, and in general over different routes, to insure communication under all conditions. They would in some cases include important submarine cables or even large wireless stations.

Tactical lines are generally of the field line class and are rapidly laid or taken up to follow the movements of the units they connect. Their name indicates their uses. They are the "combat lines" which late improvements in wire, transportation, and instruments have made possible.

FIELD TRANSPORTATION.

In addition to wagons and packs for ordinary transportation, the Signal Corps has found it necessary to devise some special vehicles for transporting and laying wire and carrying such equipment as wireless sets, lances, etc.

The Army is now equipped with a number of efficient wire carts. This type of cart is drawn by two horses and supports two spools which are rotated by means of a sprocket wheel and chain rotated by the wheels of the cart. Each of the reels of this cart will hold 2½ miles of field wire and a line can be laid as rapidly as the horses are made to travel. The line is paid out from the reel on the ground and is laid to one side of the road by a man on horseback in rear, by means of the wire pike descriped in chapter 8.

In case a wire cart is not available, field wire lines may be laid and recovered by means of quartermaster' escort wagons and ordinary take-up or pay-out reels.

For handling the small insulated buzzer wire, which is furnished on one-half mile spools, the wire carrier and hand reel answer every purpose either on foot or mounted.

The instrument wagons are either spring wagons, or the regular Army escort wagon, provided with paulins or wagon covers, in which instruments, light tools, repair parts, etc., may be transported.

The lance truck is a wagon with a high seat and long reach, suited for the transportation of lance poles. Four mules suffice for this load under ordinary conditions.

Special pack chests are provided for the Signal Corps supplies, and the present field wireless pack set, which is carried on three mules, requires special fittings for the aparejos.

WIRE USED IN FIELD OPERATIONS.

For the permanent military lines, No. 9 galvanized wire, weighing 320 pounds to the mile, is the standard.

For semipermanent lines, such as lance lines, No. 14 galvanized wire, weighing about 100 pounds per mile, is used.

The two kinds of wire used in field lines are known, respectively, as "field wire" and "buzzer wire." The former corresponds with the "field cable" used abroad. Our field wire, described in chapter 8 of this manual, has a tensile strength of over 300 pounds and weighs 70 pounds per mile. Five miles of it may be carried on the drums of the latest type wire cart. Its strength and insulation are little impaired by wagons and troops passing over it. It is very pliable and lies flat on irregular ground. As it is laid, mounted men follow the reel cart with pikes or lances having hooks on the ends, either placing the wire out of the way on the road, or if need be, hooking it up on trees. It is difficult to break or injure this wire unintentionally. If found broken, a temporary splice should be made. This is done by tying the ends together with a hard knot, leaving about a foot of each free. The insulation is then removed from the ends for several inches and the bare wires twisted together.

Buzzers or camp telephones may be quickly connected to field wire by means of "Type A buzzer connectors." These connectors are furnished with sharp teeth that pierce the insulation readily and, when withdrawn, damage the wire very little.

In every way this type of wire seems eminently suited for field lines, the only objection being its cost, which is about $75 per mile.

A small wire of this class, suitable for laying from a hand reel, is called "buzzer wire," described in chapter 8 of this manual. This wire weighs about 10 pounds per mile and is put up on half-mile spools. This permits paying out the wire from a simple holder from horseback and its recovery by means of a hand reel. This wire is used for short lines or for emergency lines over rough ground where the heavier field wire can not be carried.

It may be useful to remember that since buzzers will operate over long stretches of bare wire laid on the ground even in wet weather, field lines of any kind of wire available may be laid in emergencies.

INSTRUMENTS FOR ELECTRICAL LINES OF INFORMATION.

Base lines and other permanent telegraph lines will, of course, make use of the familiar commercial apparatus. Morse instruments of various portable forms, such as the box relay, main-line sounder, or pocket relay, will be used on semipermanent lines wherever practicable. These require, however, large battery equipment and well-insulated lines, and in bad weather the instruments are difficult to keep in adjustment.

THE BUZZER.

On our field lines the buzzer in one of its forms is almost universally used. This instrument was introduced into our service about 1890 and first showed its capabilities in the Philippine and China campaigns. In its present form of "service buzzer" it combines a complete telegraph and telephone station, including the necessary batteries. Its capacity for working over circuits impossible for any other telegraph instruments, such as bare-wire lines laid on the ground, through wire of wire fences, or railroad rails, or, more incredible still, through considerable breaks in the line when the ends lie on the ground, makes it the ideal instrument for field lines.

To open a station it is only necessary to fasten the buzzer connector with flexible cord from one binding post to the field wire, and from the other binding post a flexible wire leads to a small ground rod or metal peg driven into the ground.

By working the key an interrupter is operated giving a high singing note, which is broken up into the dots and dashes of the Morse alphabet. These correspond to vibratory electrical impulses which go out on the line and are heard in the telephone receiver at the distant station. The efficiency of the buzzer under the difficult conditions stated is due to the marvelous sensitiveness of the telephone receiver to these rapidly pulsating currents. In practically the same circuit as the interrupter is a telephone transmitter, and when the button switch on this is depressed the instrument becomes at once converted into a very efficient telephone set.

THE CAMP TELEPHONE.

This instrument described in chapter 3 has all the component parts of the most complete telephone. The box is very strong and weatherproof and has a strap for convenience in carrying. The connections are very simple and easily repaired when deranged. It can be connected to field lines and the ground in the same way as the buzzer. Its common use, however, is for camp lines where, with its generator and call bell, it is specially suited for connection with the camp switchboard described in chapter 8.

FIELD INDUCTION TELEGRAPH.

On semipermanent lines, especially where business over them is heavy, the continual use of the buzzer is very fatiguing to Morse operators. The induction telegraph set described in chapter 2 has been devised especially for this class of lines. Operating the key of this instrument sends out impulses of high voltage over the line and relays. These relays are very sensitive and operate with a remarkably small current. As a result of the voltage increase and relay sensibility, three dry cells of battery will work the sets over hundreds of miles of iron wire, over ordinary circuits where the insulation leakage permits the escape of 95 per cent of the current. Doing away, as it does, with carrying large amounts of battery, it is believed to be a useful intermediate instrument between the buzzer and the regular telegraph installation.

SELECTION OF INSTRUMENTS.

The buzzer, the telephone, and telegraph each has fairly well defined rôles in operating electrical lines of information. The buzzer is the pioneer which clears the way, follows up the fighting line, and can operate over any kind of a line. Its function as a telegraph instrument is the paramount one on account of its reliability, although, as stated, it is a good telephone when the wire is in proper condition. The camp telephone is most useful in camp administration lines or over semipermanent lines in general where telephone service seems desirable.

The telegraph is standard where lines are established and where the volume and importance of business become great. To the trained operator there is nothing to equal the clearness and certainty with which a message on a Morse sounder is delivered, and such operation is the ultimate excellence toward which military lines aim.

The decision as to when the telephone or telegraph should be installed or used is governed by the following considerations:

The telephone does not require trained operators.

The telephone may be used for direct, and consequently confidential, communication between officers.

Time is saved, compared with telegraphy, especially when the users are accustomed to the telephone.

The telegraph is superior to the telephone in the following ways:

Accuracy.—A written message, spelled out by telegraphy, written and delivered, has an obvious advantage over one delivered by word of mouth.

Reliability.—In the field, especially when the wind is blowing in the ears and various other noises tend to confuse, it is very hard to distinguish in the telephone words which sound alike. This is especially confusing to an enlisted man unused to expressions common in military messages. The sharp signals on the buzzer or sounder are much more reliable.

Speed.—It is found in the case of written messages transmitted by buzzer and telephone that, owing to frequent repetitions required by telephone, the buzzer will generally exceed it in speed.

From the foregoing considerations it is evident that officers should, when time permits, always write out their messages in proper form. The use of the telephone should be restricted to communication between officers. The direction to an operator verbally to send messages by telegraph is inadvisable. Sending messages by dictation through the telephone invites almost certain errors.

Miscellaneous Tables and Information.

UNITS OF RESISTANCE.

The unit of resistance now universally used is the international ohm. The following multiples of this unit are sometimes employed:

	Ohms.
Megohm=	1,000,000.
Microhm=	0.000,001.

The following table gives the value of the principal practical units of resistance which existed previous to the establishment of the international units:

Unit.	International ohm.	B. A. ohm.	Legal ohm, 1884.	Siemens' ohm.
International ohm	1.000	1.0136	1.0028	1.0630
B. A. ohm	.9866	1.000	.9894	1.0488
Legal ohm	.9972	1.0107	1.000	1.0600
Siemens' ohm	.9407	.9535	.9434	1.000

Thus, to reduce British Association ohms to international ohms we divide by 1.0136, or multiply by 0.9866; and to reduce legal ohms to international ohms we divide by 1.0028, or multiply by 0.9972, etc.

SPECIFIC RESISTANCE.

Let l=length of the conductor.
A=cross section of the conductor.
R=resistance of the conductor.
ρ=specific resistance of the conductor.

Then

$$R=\rho\frac{l}{A},$$

or

$$\rho=R\frac{A}{l}.$$

If l is measured in centimeters and A in square centimeters, ρ is the resistance of a centimeter cube of the conductor. If l is measured in inches and A is square inches, ρ is the resistance of an inch cube of the conductor.

In telegraph and telephone practice, specific resistance is sometimes expressed as the *weight per mile-ohm*, which is the weight in pounds of a conductor 1 mile long having a resistance of 1 ohm.

Another common way of expressing specific resistance is in terms of *ohms per mil-foot*, i. e., the resistance of a round wire 1 foot long and 0.001 inch in diameter; l is then measured in feet and A in circular mils.

Microhms per inch cube=0.3937×microhms per centimeter cube.

Pounds per mile-ohm=57.07×microhms per centimeter cube×specific gravity.

Ohms per mil-foot=6.015×microhms per centimeter cube.

Specific conductivity is the reciprocal of specific resistance. If c=specific condutivity,

$$R=\frac{l}{cA},$$

$$c=\frac{l}{RA},$$

$$c=\frac{1}{\rho}.$$

By relative or percentage conductivity of a sample is meant 100 times the ratio of the conductivity of the sample at standard temperature to the conductivity of a conductor of the same dimensions made of the standard material and at standard temperature. If ρ_0 is the specific resistance of the sample at standard temperature and ρ_s is the specific resistance of the standard at standard temperature, then

$$\text{Percentage conductivity}=100\frac{\rho_s}{\rho_0}.$$

In comparing different materials, the specific resistance should always be determined at the standard temperature, which is usually taken as 0° centigrade. If it is inconvenient to measure the resistance of the sample at the standard temperature, this may be readily calculated if the temperature coefficient a of the sample is known, i. e.,

$$p_0 = \frac{\rho_t}{1+at}.$$

where ρ_t is the specific resistance at temperature t.

Matthiessen's standard of conductivity, which is the commercial standard, is a copper wire having the following properties at the standard temperature of 0° centigrade:

Specific gravity	8. 89.
Length	1 meter.
Weight	1 gram.
Resistance	0. 141729 ohms.
Specific resistance	1. 594 microhms per cubic centimeter.
Relative conductivity	100 per cent.

Specific resistance, relative resistance, and relative conductivity of conductors.

[Referred to Matthiessen's standard.]

Metals.	Resistance in microhms at 0° C.		Relative resistance.	Relative conductivity.
	Centimeter cube.	Inch cube.		
			Per cent.	*Per cent.*
Silver, annealed	1. 47	0. 579	92. 5	108. 2
Copper, annealed	1. 55	. 610	97. 5	102. 6
Copper (Matthiessen's standard)	1. 594	. 6276	100	100.
Gold (99.9 per cent pure)	2. 20	. 865	138	72. 5
Aluminum (99 per cent pure)	2. 56	1. 01	161	62. 1
Zinc	5. 75	2. 26	362	27. 6
Platinum, annealed	8. 98	3. 53	565	17. 7
Iron	9. 07	3. 57	570	17. 6
Nickel	12. 3	4. 85	778	12. 9
Tin	13. 1	5. 16	828	12. 1
Lead	20. 4	8. 04	1, 280	7. 82
Antimony	35. 2	13. 9	2, 210	4. 53
Mercury	94. 3	37. 1	5, 930	1. 69
Bismuth	130.	51. 2	8, 220	1. 22
Carbon (graphitic)	2, 400–42, 000	950–16, 700		
Carbon (arc light)	about 4, 000	about 1, 590		
Selenium	6×10^{10}	2.38×10^{10}		

Resistances of liquid conductors.

Liquids at 18° C.	Ohms per centimeter cube.	Ohms per inch cube.
Pure water	2, 650.	1, 050.
Sea water	30.	11. 8
Sulphuric acid:		
5 per cent	4. 86	1. 93
30 per cent	1. 37	. 544
80 per cent	9. 18	3. 64
Nitric acid, 30 per cent	1. 29	. 512
Zinc sulphate, 24 per cent	21. 4	8. 54

TEMPERATURE COEFFICIENT.

The resistance of a conductor varies with the temperature of the conductor.

Let R_0=resistance at 0°.
R =resistance at t°.
Then $R = R_0 (1+a\ t)$.

a is called the *temperature coefficient* of the conductor; 100 a is the percentage change in resistance per degree change in temperature.

The following values of temperature coefficients have been found for temperatures measured in degrees Centigrade and in degrees Fahrenheit. It is to be noted that the coefficients vary considerably with the purity of the conductor.

Pure metals.	Centigrade.[a]	Fahrenheit.[a]
Silver, annealed	0.00400	0.00222
Copper, annealed	.00428	.00242
Gold (99.9 per cent)	.00377	.00210
Aluminum (99 per cent)	.00423	.00235
Zinc	.00406	.00226
Platinum, annealed	.00247	.00137
Iron	.00625	.00347
Nickel	.0062	.00345
Tin	.00440	.00245
Lead	.00411	.00228
Antimony	.00389	.00216
Mercury	.00072	.00044
Bismuth	.00354	.00197

Matthiessen's formula for soft copper wire $R=R_0\ (1+.00387t+.00000597t^2)$.

The wire used by Matthiessen was as pure as could be obtained at the time (1860), but in reality contained considerable impurities; the above formula, therefore, is not generally applicable. Later experiments have shown that for all practical work the above equation for copper wire may be written $R=R_0\ (1+.0042t)$ for t in ° C.

WIRE GAUGES.

The sizes of wires are ordinarily expressed by an arbitrary series of numbers. Unfortunately there are several independent numbering methods, so that it is always necessary to specify the method or wire gauge used. The following table gives the numbers and diameters in decimal parts of an inch for the various wire gauges used in this country and England:

Number of wire gauge.	Roebling or Washburn & Moens.	Brown & Sharpe.	Birmingham or Stubs	English legal standard.	Old English or London.
	Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*
6–0	0.460	....	....	0.464	....
5–0	.430	....	....	.432	....
4–0	.393	0.4600	0.454	.400	0.4540
3–0	.362	.4096	.425	.372	.4250
2–0	.331	.3648	.380	.348	.3800
0	.307	.3249	.340	.324	.3400
1	.283	.2893	.300	.300	.3000
2	.263	.2576	.284	.276	.2840
3	.244	.2294	.259	.252	.2590
4	.225	.2043	.238	.232	.2380
5	.207	.1819	.220	.212	.2200
6	.192	.1620	.203	.192	.2030
7	.177	.1443	.180	.176	.1800
8	.162	.1285	.165	.160	.1650
9	.148	.1144	.148	.144	.1480
10	.135	.1019	.134	.128	.1340
11	.120	.09074	.120	.116	.1200
12	.105	.08081	.109	.104	.1090
13	.092	.07196	.095	.092	.0950
14	.080	.06408	.083	.080	.0830
15	.072	.05706	.072	.072	.0720
16	.063	.05082	.065	.064	.0650
17	.054	.04525	.058	.056	.0580
18	.047	.04030	.049	.048	.0490
19	.041	.03589	.042	.040	.0400
20	.035	.03196	.035	.036	.0350
21	.032	.02846	.032	.032	.0315
22	.028	.02534	.028	.028	.0295
23	.025	.02257	.025	.024	.0270
24	.023	.02010	.022	.022	.0250
25	.020	.01790	.020	.020	.0230
26	.018	.01594	.018	.018	.0205
27	.017	.01419	.016	.0164	.01875
28	.016	.01264	.014	.0148	.01650
29	.015	.01125	.013	.0136	.01550
30	.014	.01002	.012	.0124	.01375
31	.0135	.00893	.010	.0116	.01225
32	.0130	.00795	.009	.0108	.01125
33	.0110	.00708	.008	.0100	.01025
34	.0100	.00630	.007	.0092	.0095
35	.0095	.00561	.005	.0084	.0090
36	.0090	.00500	.004	.0076	.0075
37	.0085	.00445	....	.0068	.0065
38	.0080	.00397	....	.0060	.0057
39	.0075	.00353	....	.0052	.0050
40	.0070	.00314	....	.0048	.0045

Roebling gauge.—Used in this country for iron and steel wire.

Brown & Sharpe gauge.—The American standard for copper wires for electrical purposes.

Birmingham gauge.—Used largely in England and also in this country for iron and steel wires for electrical purposes.

LAW OF THE BROWN & SHARPE GAUGE.

The diameters of wires on the B. & S. gauge are obtained from the geometric series in which No. 0000=0.4600 inch and No. 36=0.005 inch, the nearest fourth significant figure being retained in the areas and diameters so deduced.

Let n = gauge number (0000 = −3; 000 = −2; 00 = −1).
d = diameter of wire in inches.

Then $d=\frac{0.3249}{1.123^n}$.

Sheathing core.—The number (N) of sheathing wires having a diameter (d) which will cover a core having a diameter (D) is

$$N=\pi\frac{D+d}{d}.$$

Tensile strength of copper wire.

COMMERCIAL STANDARDS.

Numbers, B. & S. gauge.	Breaking weight.		Numbers, B. & S. gauge.	Breaking weight.	
	Hard-drawn.	Annealed.		Hard-drawn.	Annealed.
	Pounds.	*Pounds.*		*Pounds.*	*Pounds.*
0000	8,310	5,650	9	617	349
000	6,580	4,480	10	489	277
00	5,226	3,553	11	388	219
0	4,558	2,818	12	307	174
1	3,746	2,234	13	244	138
2	3,127	1,772	14	193	109
3	2,480	1,405	15	153	87
4	1,967	1,114	16	133	69
5	1,559	883	17	97	55
6	1,237	700	18	77	43
7	980	555	19	61	34
8	778	440	20	48	27

The strength of soft copper wire varies from 32,000 to 36,000 pounds per square inch, and of hard copper wire from 45,000 to 68,000 pounds per square inch, according to the degree of hardness.

The above table is calculated for 34,000 pounds for soft wire and 60,000 pounds for hard wire, except for some of the larger sizes, where the breaking weight per square inch is taken at 50,000 pounds for 0000, 000, and 00; 55,000 for 0; and 57,000 pounds for 1.

Hard-drawn copper telephone and telegraph wire.

COMMERCIAL VALUES.

Size B. & S. guage.	Resistance per mile.	Breaking strength.	Weight per mile.	Furnished in coils as follows.	Approximate size E. B. B. iron wire equal to copper.
	Ohms.	*Pounds.*	*Pounds.*	*Miles.*	
9	4.30	625	209	1	2
10	5.40	525	166	1.2	3 Iron-wire guage.
11	6.90	420	131	.52	4 Iron-wire guage.
12	8.70	330	104	.65	6 Iron-wire guage.
13	10.90	270	83	1.20	6½ Iron-wire guage.
14	13.70	213	66	1.50	8 Iron-wire guage.
15	17.40	170	52	2.00	9 Iron-wire guage.
16	22.10	130	41	1.20	10

In handling this wire the greatest care should be observed to avoid kinks, bends, scratches, or cuts. Joints should be made only with copper splicing sleeves and connectors.

On account of its conductivity being about five times that of Ex. B. B. iron wire, and its breaking strength over three times its weight per mile, copper may be used of which the section is smaller and the weight less than an equivalent iron wire, allowing a greater number of wires to be strung on the poles.

Besides this advantage, the reduction of section materially decreases the electrostatic capacity, while its nonmagnetic character lessens the self-induction of the line, both of which features tend to increase the possible speed of signaling in telegraphing, and to give greater clearness of enunciation over telephone lines, especially those of great length.

Standard copper strands.

COMMERCIAL STANDARDS.

C. M.	Wires. Number.	Wires. Size.	Outside diameter.	Weight per 1,000 feet.
		Inch.	*Inches.*	*Pounds.*
2,000,000	127	0.1255	1.632	6,100
1,950,000	127	.1239	1.611	5,948
1,900,000	127	.1223	1.590	5,795
1,850,000	127	.1207	1.569	5,643
1,800,000	127	.1191	1.548	5,490
1,750,000	127	.1174	1.526	5,338
1,700,000	91	.1367	1.504	5,185
1,650,000	91	.1347	1.482	5,033
1,600,000	91	.1326	1.459	4,880
1,550,000	91	.1305	1.436	4,728
1,500,000	91	.1284	1.412	4,575
1,450,000	91	.1262	1.388	4,423
1,400,000	91	.1240	1.364	4,270
1,350,000	91	.1218	1.340	4,118
1,300,000	91	.1195	1.315	3,965
1,250,000	91	.1172	1.289	3,813
1,200,000	61	.1403	1.263	3,660
1,150,000	61	.1373	1.236	3,508
1,100,000	61	.1343	1.209	3,355
1,050,000	61	.1312	1.181	3,203
1,000,000	61	.1280	1.152	3,050
950,000	61	.1247	1.122	2,898
900,000	61	.1214	1.093	2,745
850,000	61	.1180	1.062	2,593
800,000	61	.1145	1.031	2,440
750,000	61	.1108	.997	2,288
700,000	61	.1071	.964	2,135
650,000	61	.1032	.929	1,983
600,000	61	.0991	.892	1,830
550,000	61	.0949	.854	1,678
500,000	61	.0905	.815	1,525
450,000	37	.1103	.772	1,373
400,000	37	.1039	.727	1,220
350,000	37	.0972	.680	1,068
300,000	37	.0900	.630	915
250,000	37	.0821	.575	763

Size, B. & S.	Wires. Number.	Wires. Size.	Outside diameter.	Weight per 1,000 feet.
		Inch.	*Inch.*	*Pounds.*
0000	19	0.1055	0.528	645
000	19	.0941	.471	513
00	19	.0837	.419	406
0	19	.0746	.373	322
1	19	.0663	.332	255
2	7	.0975	.293	203
3	7	.0866	.260	160
4	7	.0771	.231	127
5	7	.0688	.206	101
6	7	.0612	.184	80
8	7	.0484	.145	50
10	7	.0386	.116	32
12	7	.0306	.092	20
14	7	.0242	.073	12
16	7	.0193	.058	8
18	7	.0151	.045	5

Carrying capacity of insulated copper wires for interior wiring.

NATIONAL ELECTRICAL CODE.

B. & S. Co.	Area.	Rubber-covered wires.	Weather-proof wires.	Area.	Rubber-covered wires.	Weather-proof wires.
	Cir. mils.	*Amperes.*	*Amperes.*	*Cir. mils.*	*Amperes.*	*Amperes.*
18	1,624	3	5	200,000	200	300
16	2,583	6	8	300,000	270	400
14	4,107	12	16	400,000	330	500
12	6,530	17	23	500,000	390	590
10	10,380	24	32	600,000	450	680
8	16,510	33	46	700,000	500	760
6	26,250	46	65	800,000	550	840
5	33,100	54	77	900,000	600	920
4	41,740	65	92	1,000,000	650	1,000
3	52,630	76	110	1,100,000	690	1,080
2	66,370	90	131	1,200,000	730	1,150
1	83,690	107	156	1,300,000	770	1,220
0	105,500	127	185	1,400,000	810	1,290
00	133,100	150	220	1,500,000	850	1,360
000	167,800	177	262	1,600,000	890	1,430
0000	211,600	210	312	1,700,000	930	1,490
....	....	....	....	1,800,000	970	1,550
....	....	....	....	1,900,000	1,010	1,610
....	....	....	....	2,000,000	1,050	1,670

Carrying capacity of stranded copper conductors for interior wiring.

NATIONAL ELECTRICAL CODE.

B. & S. gauge.	Area actual C. M.	Number of strands.	Size of strand, B. & S. gauge.	Amperes.
19	1,288	....	....	....
18	1,624	....	....	....
17	2,048	....	....	....
16	2,583	....	....	6
15	3,257	....	....	....
14	4,107	....	....	12
12	6,530	....	....	17
....	9,016	7	19	21
....	11,368	7	18	25
....	14,336	7	17	30
....	18,081	7	16	35
....	22,799	7	15	40
....	30,856	19	18	50
....	38,912	19	17	60
....	49,077	19	16	70
....	60,088	37	18	85
....	75,776	37	17	100
....	99,064	61	18	120
....	124,928	61	17	145
....	157,563	61	16	170
....	198,677	61	15	200
....	250,527	61	14	235
....	296,387	91	15	270
....	373,737	91	14	320
....	413,639	127	15	340

For aluminum wire the carrying capacity of any given size is to be taken as 84 per cent of the value given in the above table.

U.S. SIGNAL CORPS

TABLES OF TEMPERATURE COEFFICIENTS

FOR REDUCING CONDUCTOR AND INSULATION RESISTANCE TO STANDARD TEMPERATURE

785
AUGUST 12, 1909
FROM J. R. W.
DRAWN W. W.
CHECKED W. W.
O.K. [signature]
APPROVED [signature]
REVISED

TEMP.	COPPER	EXPER. CORE	KERITE	SAFETY	TELEPHONE	
0	1.1538					
1	1.1509					1.026
2	1.1480					1.053
3	1.1451					1.080
4	1.1422					1.108
5	1.1393					1.137
6	1.1364					1.167
7	1.1336					1.197
8	1.1308					1.228
9	1.1280					1.260
10	1.1252					1.293
11	1.1224					1.326
12	1.1196					1.361
13	1.1168					1.396
14	1.1141					1.433
15	1.1113					1.470
16	1.1086					1.508
17	1.1059					1.547
18	1.1032					1.587
19	1.1005					1.629
20	1.0978		.2706	.4399		1.671
21	1.0952		.2725	.4472		1.715
22	1.0925		.2747	.4547		1.759
23	1.0899		.2774	.4625		1.805
24	1.0873		.2804	.4705		1.852
25	1.0846		.2839	.4787		1.900
26	1.0820		.2877	.4869		1.949
27	1.0794		.2921	.4959		2.000
28	1.0769		.2968	.5049		2.052
29	1.0743		.3020	.5141		2.105
30	1.0717	.3625	.3078	.5237		2.160
31	1.0692	.3827	.3141	.5335		2.216
32	1.0667	.4034	.3209	.5437		2.274
33	1.0641	.4244	.3283	.5542		2.333
34	1.0616	.4456	.3363	.5648		2.394
35	1.0591	.4672	.3449	.5759		2.456
36	1.0566	.4891	.3543	.5873		2.520
37	1.0542	.5111	.3644	.5990		2.586
38	1.0517	.5333	.3752	.6112		2.653
39	1.0492	.5557	.3869	.6236		2.722
40	1.0467	.5781	.3995	.6351	.0488	2.796
41	1.0443	.6006	.4131	.6498	.0594	2.865
42	1.0419	.6232	.4276	.6635	.0723	2.940
43	1.0395	.6456	.4433	.6776	.0873	3.016
44	1.0371	.6681	.4601	.6921	.1048	3.091
45	1.0347	.6905	.4782	.7071	.1251	3.175
46	1.0323	.7127	.4977	.7226	.1482	3.258
47	1.0300	.7348	.5187	.7386	.1751	3.342
48	1.0276	.7566	.5413	.7551	.2062	3.429
49	1.0252	.7784	.5655	.7721	.2412	3.518
50	1.0229	.7999	.5917	.7897	.2807	3.610
51	1.0206	.8211	.6199	.8078	.3251	
52	1.0182	.8421	.6503	.8265	.3747	
53	1.0159	.8626	.6831	.8458	.4300	
54	1.0136	.8833	.7184	.8658	.4912	S U CABLE CO SPEC 429
55	1.0113	.9034	.7566	.8864	.5587	
56	1.0090	.9233	.7979	.9076	.6328	
57	1.0068	.9429	.8426	.9296	.7162	
58	1.0045	.9622	.8909	.9523	.8017	
59	1.0023	.9812	.9433	.9758	.8971	
60	1.0000	1.0000	1.0000	1.0000	1.0000	1.00
61	.9978	1.0185	1.0616	1.0251	1.1106	
62	.9956	1.0368	1.1281	1.0510	1.2290	
63	.9933	1.0548	1.2010	1.0777	1.3552	
64	.9911	1.0726	1.2800	1.1054	1.4881	
65	.9889	1.0902	1.3660	1.1340	1.6316	1.16
66	.9867	1.1077	1.4597	1.1636	1.7867	
67	.9846	1.1251	1.5618	1.1943	1.9397	
68	.9824	1.1423	1.6772	1.2260	2.1054	
69	.9802	1.1595	1.7952	1.2587	2.2789	
70	.9781	1.1767	1.9285	1.2927	2.4600	1.35
71	.9759	1.1939	2.0744	1.3276	2.6485	
72	.9738	1.2112	2.2343	1.3641	2.8444	
73	.9717	1.2285	2.4097	1.4017	3.0474	
74	.9695	1.2461	2.6023	1.4407	3.2575	
75	.9674	1.2638	2.8410	1.4811	3.4744	1.60
76	.9653	1.2817	3.0469	1.5228	3.6982	
77	.9632	1.3000	3.3035	1.5647	3.9133	
78	.9611	1.3187	3.5865	1.6110	4.1658	
79	.9591	1.3378	3.8988	1.6728	4.4096	
80	.9570	1.3574	4.2438	1.7056	4.6600	1.90
81	.9549	1.3775	4.6256	1.7556	4.9172	
82	.9529	1.3984	5.0483	1.8073	5.1812	
83	.9508	1.4196	5.5169	1.8610	5.4523	
84	.9488	1.4424	6.0371	1.9167	5.7307	
85	.9468	1.4656	6.6149	1.9744	6.0167	2.20
86	.9448	1.4899	7.2577	2.0343	6.3108	
87	.9428	1.5152	7.9734	2.0964	6.6138	
88	.9408	1.5418	8.7713	2.1609	6.9259	
89	.9388	1.5697	9.6617	2.2278	7.2481	
90	.9368	1.5988	10.6556	2.2973	7.5812	2.60
91	.9348	1.6297	11.7695	2.3694	7.9261	
92	.9328	1.6621	13.0158	2.4443	8.2841	
93	.9308	1.6965	14.4130	2.5223	8.6564	
94	.9288	1.7327	15.9814	2.6028	9.0446	
95	.9268	1.7706	17.7443	2.6858	9.4500	
96	.9249	1.8120	19.7253	2.7727	9.8749	
97	.9231	1.8553	21.9598	2.8646	10.3211	
98	.9211	1.9014	24.4782	2.9587	10.7912	
99	.9192	1.9505	27.3318	3.0566	11.2776	
100	.9173	2.0027	30.3383	3.1584	11.8133	
101	.9154	2.0586			12.3718	
102	.9135	2.1182			12.9666	
103	.9116	2.1819			13.6019	
104	.9097	2.2501			14.2825	
105	.9079	2.3231			15.0135	
106	.9060	2.4014			15.8071	
107	.9040	2.4859			16.6518	
108	.9022	2.5764			17.5734	
109	.9004	2.6733			18.5746	
110	.8986	2.7783			19.6647	
111	.8968				20.8983	
112	.8949				22.1398	
113	.8931				23.5916	
114	.8913				25.1685	
115	.8895				26.9095	
116	.8877				28.8372	
117	.8859				30.9774	
118	.8841				33.3602	
119	.8824				36.0208	
120	.8806				39.0000	

Temperature in Degrees, Fahrenheit

Copper: Reduction of copper resistances to 60° F

Exper. Core: Temperature coefficients for experimental core of 40% and 30%. Use this table for compounds of specifications Nos 419, 420 and 421 only

Kerite: Data from W. U. Tel Co. Reduction to 60° F

Safety: Reduction to 60° F. Use this table for 40% compound and rubber compound of specifications previous to No 419

Telephone: Standard Underground Cable Company, Telephone. Use this table for all dry paper insulated telephone cable

Hooper's Material (Warren). This table is logarithmic. Correct by using dif bet. observed and standard temp in degrees. Use this table for Okonite, Bishop, Habishaw, India Rub and Gutta Percha Company

Fig. 9-33.—TEMPERATURE COEFFICIENTS.

(417)

USEFUL CONSTANTS AND FORMULÆ.

[From Electrical Tables and Formulæ, Clark and Sabine.]

COPPER.

The specific gravity of copper wire, according to the best authorities, is about 8.899.

One cubic foot weighs about 550 pounds.

One cubic inch weighs 0.32 pound.

The ordinary breaking weight of copper wire is about 17 tons per square inch, varying greatly, however, according to the size and degree of hardness.

The weight per nautical mile of any copper wire is about $\frac{d^2}{55}$ pounds, d being the diameter in mils.

The weight per nautical mile of a copper strand is about $\frac{d^2}{70.4}$ pounds.

The weight per statute mile of any copper wire is $\frac{d^2}{63}$ pounds. A mile of 64 mils diameter, wire weighs in practice from 63 to 66 pounds.

The diameter of any copper wire weighing w pounds per nautical mile is $7.4 \sqrt{w}$ mils.

The diameter of any copper wire weighing w pounds per statute mile is $7.94 \sqrt{w}$ mils.

The diameter of a copper strand weighing w pounds per nautical mile is about $8.4 \sqrt{w}$ mils.

The approximate resistance of a nautical mile of pure copper weighing 1 pound is, at 32° F., 1,091.22 ohms; at 60° F., 1,155.48 ohms; at 75° F., 1,192.45 ohms.

The resistance per nautical mile of any pure copper wire or strand weighing w pounds is $\frac{1192.45}{w}$ at 75° F.

The resistance per nautical mile of any pure copper wire d mils in diameter is $\frac{65306}{d^2}$ ohms at 75 F.

The resistance per statute mile of any pure copper wire is $\frac{54892}{d^2}$ ohms at 60° F.

The resistance per nautical mile of any pure copper strand is $\frac{83964}{d^2}$ ohms at 75° F.

The resistance per nautical mile of a cable conductor is equal to 120,000 divided by the product of the percentage conductivity of the copper and its weight per nautical mile in pounds.

The resistance of a statute mile of pure copper weighing 1 pound is 1002.4 ohms at 60° F. 51 mils diameter copper wire of good quality has a resistance of about 19 ohms.

The resistance of a statute mile of pure copper weighing w pounds is $\frac{1002.4}{w}$ ohms at 60° F.

The resistance of any pure copper wire L inches in length, weighing n grains, is $\frac{.001516 \times L^2}{n}$ ohms.

IRON.

The weight of any iron wire per nautical mile is $\frac{d^2}{62.6}$ pounds, d being its diameter in mils.

The weight of any iron wire per statute mile is $\frac{d^2}{72}$ pounds.

The diameter of any iron wire weighing w pounds per statute mile $=8.49\sqrt{w}$ mils.

The diameter of any iron wire weighing w pounds per nautical mile $=7.91\sqrt{w}$ mils.

The conductivity of ordinary galvanized-iron wire averages about one-seventh that of pure copper.

The resistance per statute mile of a galvanized-iron wire is about $\frac{360,000}{d^2}$ ohms, at 60° F.

CABLE TANKS.

To find the capacity of a circular tank:

Let r = radius in inches of eye.
R = radius in inches of the tank.
d = diameter in inches of the cable.
h = height in inches of tank.
$\pi = 3.1416$.

Total length of cable in feet $\frac{\pi h}{d^2}(R^2 - r^2) \div 12$.

DISTANCE—SOUND.

Distance from shore—Measurement by sound.—It sometimes happens that the distance of the ship from shore is required to be known, and a measurement by sound may be resorted to. For this purpose a gun is fired and the interval between the flash and the sound noted.

Let D = distance in nautical miles.
T = temperature of air in degree Centigrade;
S = interval in seconds;

then

$$D = 0.179\ S\sqrt{1+0.00374\ T}.$$

Example: A ship fired a cannon, and the sound was heard six and one-half seconds after the flash was seen. The temperature of the air was 15° C. Required, the distance (D) of the ship.

$$D = 0.179 \times 6\tfrac{1}{2}\sqrt{1+0.00374 \times 15} = 1.2 \text{ nautical miles.}$$

For converting statute miles to nautical miles, multiply by 1.1528. Nautical mile and knot are synonymous, but nautical mile is used to express distance and knot is used to express speed.

LIST OF INSTALLED SIGNAL CORPS SUBMARINE CABLES, SEPTEMBER 2, 1915.

This list is subject to change, however when a submarine cable is replaced a new number is assigned.

CABLES IN THE UNITED STATES.

No.	Location.	Conductors.	Date laid.
	MAINE.		
267	Fort Williams—Fort Levett	40	1908
311	....do	46	1912
257	House Island—Fort Levett	50	1908
345	....do	14	1914
256	House Island—Fort Preble	40	1908
306	....do	20	1910
349	....do	9	1914
266	Fort McKinley—Long Island	6	1908
309	Fort McKinley—Peaks Island	22	1911
264	....do	24	1908
350	....do	8	1914
260	Fort Levett—Peaks Island	12	1908
261	....do	20	1908
346	....do	14	1914
128	Fort McKinley—Fort Lyon	4	1903
265	....do	20	1908
	NEW HAMPSHIRE		
352	Fort Constitution—New Reservation	10	1914
348	Fort Constitution—Fort Stark	34	1914
131	Fort Stark—Fort Foster	8	1905
332	....do	34	1914
351	F. C. Station—Cable Pole, Fort Foster	34	1914
	MASSACHUSETTS.		
135	Long Island—Moon Head	2	1904
252	Long Island—Moon Head (North Cable)	2	1908
138	Fort Andrews—Fort Revere	2	1904
236	....do	50	1907
237	....do	50	1907
327	Deer Island—Fort Standish	104	1913
226	Fort Heath—Nahant	40	1907
307	Fort Heath—Deer Island	24	1910
231	Fort Standish—Fort Warren	30	1907
232	....do	40	1907
274	Fort Warren—Fort Andrews	60	1909
275	....do	40	1909
238	Fort Revere—Point Allerton	40	1907
239	Point Allerton—Strawberry Hill	20	1907
253	Fort Strong—Fort Standish	40	1908
328	....do	44	1913
136	Fort Strong—Fort Warren	6	1898
320	Fort Rodman—Richetson Point	1	1902
321	....do	1	1902
	RHODE ISLAND.		
277	Fort Adams—Fort Wetherill	40	1909
141	Fort Wetherill—Head of Mackerel Cove	1	1902
279	Fort Greble—Fort Kearney	20	1909
280	Fort Getty—Fort Greble	20	1909
	NEW YORK.		
298	Fort Terry—Fort Michie	6	1912
344	Fort Michie—Fort H. G. Wright	10	1914
299	Fort H. G. Wright—Fort Mansfield, R. I	6	1912
273	Fort H. G. Wright—Averys Point, Conn	2	1909
313	....do	22	1912
272	Fort Slocum—New Rochelle (Q. M. C. cable)	20	1909
312	Fort Slocum—New Rochelle	1	1912
305	Fort Totten—Fort Schuyler	100	1910
220	Governors Island—Barge Office (Q. M. C. cable)	20	1909
330	Fort Wood—Ellis Island	2	1913
251	Fort Hamilton—Fort Wadsworth	50	1908
295	....do	104	1910
329	Fort Wadsworth—Fort Hancock, N. J	24	1914
353	Ellis Island—Barge Office	14	1915

CABLES IN THE UNITED STATES—Continued.

No.	Location.	Con-duct-ors.	Date laid.
	DELAWARE.		
271	Fort Du Pont—Fort Delaware	20	1908
203	Fort Delaware—Fort Mott, N. J	9	1905
293	....do	20	1909
	MARYLAND.		
292	Fort Howard—Fort Smallwood	40	1909
269	Fort Carroll—Fort Armistead	40	1908
175	Fort Washington—Fort Hunt, Va	50	1905
326	Fort Howard—Fort Carroll	24	1915
	VIRGINIA.		
301	Fort Monroe—Fort Wool	54	1913
174	Around McGinnis Land (Fort Monroe)	8	1905
	NORTH CAROLINA.		
316	Fort Caswell—Southport	2	1910
	SOUTH CAROLINA.		
300	Fort Moultrie—Fort Sumpter	44	1913
177	....do	1	1903
	FLORIDA.		
208	Fort Dade—Fort De Soto	9	1906
213	Fort Dade—Shaws Point	1	1906
205	Fort De Soto, main base line	6	1905
248	Fort Barrancas—Fort Pickens	2	1907
314	....do	24	1913
315	....do	2	1910
249	Fort McRee—Fort Pickens	2	1907
297	....do	2	1911
325	....do	24	1913
245	Fort McRee—Fort Barrancas	2	1907
318	Fort Taylor—Martello Tower	10	1911
	ALABAMA.		
281	Fort Morgan—Fort Gaines	6	1908
	LOUISIANA.		
335	Fort St. Philip—Fort Jackson	4	1913
	TEXAS.		
342	Fort Crockett—Fort San Jacinto	10	1914
	CALIFORNIA.		
188	Presidio—Fort Baker	3	1904
189	Fort Baker—Fort McDowell	3	1898
282	....do	30	1909
338	Alcatraz Island—Angel Island	20	1913
284	Fort Barry—Fort Miley	50	1909
341	Fort Rosecrans—Fort Pio Pico	20	1913
369	Fort Baker—Presidio San Francisco	52	1915
	WASHINGTON.		
336	Fort Columbia—Fort Stevens, Oreg	44	1913
337	Fort Columbia—Fort Canby	24	1913
192	Fort Flagler—Fort Worden	10	1904
355	....do	44	1914
354	Fort Flagler—Fort Casey	44	1914
370	Fort Casey—Fort Worden	44	1915
317	....do	6	1911
195	Fort Lawton—Fort Ward,	1	1905
287	Fort Lawton—Fort Flagler	1	1906
367	Discovery Bay—Between station (2) and end of aerial line	22	1915
368	Discovery Bay—Between stations (2) and (3)	22	1915

CABLES IN PANAMA.

No.	Location.	Conduct-ors.	Date laid.
	PANAMA.		
371	Fort Sherman—Fort De Lesseps	50	1915
372	Fort De Lesseps—Cristobal Mole	6	1915
373	Fort De Lesseps—Fort Randolph	30	1915
374	Galeta Point—Largo Remo Point	20	1915
375	Fort Amador—Naos Island, Fort Grant	100	1915
376	Naos Island, Fort Grant—Paitillo Point	30	1915
377	Naos Island, Fort Grant—Batelle Point	40	1915
378	Naos Island, Fort Grant—Perico Island, Fort Grant	40	1915
379	Perico Island, Fort Grant—Flamenco Island, Fort Grant	50	1915
380	Flamenco Island, Fort Grant—San Jose Rock	6	1915

CABLES IN THE PHILIPPINE ISLANDS.

343	Malinta Cove—Bayakaguin Point	2	1913
339	Fort Mills—Caballo Island	20	1913
340	Caballo Island—El Fraile Island	20	1913
324	Manila—Fort Mills	1	1913
356	Fort Frank—Fort Drum	50	1914

CABLES IN ALASKA.

43	Safety—St. Michael (abandoned; partly recovered Aug. 15, 1905)	1	1901
44	Juneau—Skagway (changed to cables Nos. 45 and 46)	1	1901
45	Juneau—Haines [1]	1	1903
46	Haines—Skagway [1]	1	1903
47	Sitka—Juneau (via Cape Fanshaw)	1	1903
48	Seattle—Sitka	1	1904
49	Sitka—Valdez	1	1904
50	Valdez—Liscum	1	1905
51	Valdez—Seward (changed to cables Nos. 59 and 60)	1	1905
52	Fanshaw—Wrangell	1	1906
53	Wrangell—Hadley	1	1906
54	Hadley—Ketchikan	1	1906
58	Sitka—Japonski Island	1	1907
59	Seward—Montague Island [2]	1	1908
60	Valdez—Montague Island [2]	1	1908
61	Cordova—Montague Island	1	1908
63	Juneau—Douglas City	1	1910
64	Cordova—Cape Whiteshed	1	1908

[1] Formed by dividing the Juneau-Skagway cable, No. 44, at Fort William H. Seward and replacing portions near Skagway.

[2] Formed by dividing the Valdez-Seward cable, No. 51, at Montague Island.

CHAPTER 10.

REQUISITIONS AND GENERAL-MAINTENANCE REGULATIONS.

REQUISITIONS FOR MAINTENANCE SUPPLIES.

Except in emergency, all property shipped from any of the Signal Corps general supply depots, except the one at Manila, P. I., and the one at Seattle, Wash., is directed shipped by the Chief Signal Officer of the Army. The amount of stock on hand at each of the supply depots is continually and directly under the observation of one office. This results in efficiency and economy in the purchase and issue of property. With one office handling all requisitions for fire-control and Signal Service property from all Army posts in continental United States, Hawaii, Porto Rico, United States territory in Cuba, and the Canal Zone, together with all requisitions from the various State militia organizations and the voluminous stock requisitions from the various property officers of the different supply depots, it is not difficult to see that the efficient and expeditious handling of papers and subsequent furnishing of supplies devolves in a great measure upon those authorized to submit requisitions.

An effort should be made to submit these requisitions semiannually only. However, it is not intended that any restriction whatever be placed regarding the number of requisitions to be submitted. First consideration should be given to having necessary supplies on hand.

A little care exercised by those who prepare requisitions is the greatest means of assisting those concerned in supplying the desired articles. The great multiplicity of Signal Corps apparatus throughout the United States and its possessions, which of necessity was invariably purchased from the lowest bidder, has been manufactured by various companies and individuals, some of whom are still in business, while others have ceased to manufacture.

Hereafter post requisitions for Signal Corps supplies will be serially numbered by means of pen and red ink. The number should be affixed in the upper left-hand corner of the front sheet and should start with No. 1 at the beginning of each fiscal year.

All post requisitions for Signal Corps supplies, except those from militia organizations and property officers of Signal Corps supply depots, should be forwarded to the Department Signal Officer of the department in which the fort for which the supplies are desired is located. The Department Signal Officer will have the requisitions examined, make such revisions as in his opinion should be made, check the serial numbers, and be sure that all provisions relating to requisitions contained in this manual have been complied with before forwarding them to the Chief Signal Officer of the Army.

All requisitions from the various State militia organizations will be serially numbered, starting with No. 1 at the beginning of each fiscal year. These requisitions will be forwarded as directed to the Chief, Division of Militia Affairs, War Department, Washington, D. C., who will carry out the provisions relative to examination contained in the preceding paragraph.

All requisitions from property officers of Signal Corps supply depots should be forwarded direct to the Chief Signal Officer of the Army when such requisitions are in accordance with all regulations contained herein.

All requisitions from Signal Corps field companies should be forwarded to Department Signal Officer, under whose control the company is operating unless by special assignment the company is controlled by another official, in the event of which the requisition should be forwarded to such official who will see that the provisions of this manual have been complied with, and then forward the requisition to the Chief Signal Officer of the Army. Field company requisitions forwarded to department signal officers shall be acted upon by that officer in a manner similar to that prescribed above for post requisitions.

The following instructions relative to items of property appearing in requisitions should be observed:

(*a*) To aid in furnishing repair parts, a number of figures illustrating apparatus in this manual are followed by a list of parts of the apparatus shown in the figure, and in most instances the part may be found in the figure by means of a reference number placed opposite name of the part. In rendering requisitions, where a part is desired, the name of the part exactly as it appears in the list, followed by the letters "P. N.," should be given, immediately succeeded by the part number in the list relating to that particular figure; also figure number should be entered. In addition, the numeral "3" in parenthesis should appear at end of item in order to distinguish between figures similarly numbered in Signal Corps Manual No. 8. It is unnnecessary to name the apparatus unless some doubt exists as to whether the part shown in the list is what is wanted or if the part desired is not listed. Where such a condition exists, a full description of the part should be furnished.

It is important to note that in listing parts of some of the apparatus it is absolutely necessary that, in addition to the above, either the manufacturer, or the size, or both be entered. As, for instance: A set of elements for a storage battery could not be intelligently furnished unless the size and the manufacturer's name are known. This also applies to the jars and sand trays for storage batteries. Bolt connectors and electrolyte for telephone storage batteries can be furnished without knowing either the size of the battery or the name of the manufacturer.

Example:

8 mica insulators for choke coil, P. N. 7, fig. 6–1 (3).
4 screws, binding, with nuts, P. N. 8, fig. 6–1 (3).
6 nuts and washers for P. N. 7, fig. 6–2 (3).
1 scale, P. N. 36, fig. 4–30 (3).

(*b*) In listing wood screws, type of head, metal employed, length, and gauge size should be entered in the order named after the word "screws." The word "bright" should not be used to indicate plain iron. Example:

2 screws, R. H. brass, 1½", No. 10, gross. (R. H. means round head.)
3 screws, F. H. iron, 1", No. 8, gross. (F. H. means flat head.)

(*c*) In listing machine screws the word "machine" should follow the word "screws" and the type of head, metal employed, length, gauge size, and number of threads per inch should follow in the order named.

Example:

2 screws, machine, F. H. iron, 1½", 8–32, gross.
6 screws, machine, R. H. brass, 1", 10–24, gross.
5 screws, machine, Fillister, Hd. iron, 1", 12–24, gross.

Where screws having a special finish such as dull nickel are desired the name of finish should follow the name of metal and where dimensions (other than number of threads per inch) are not of commercial standard a sketch illustrating such dimensions should accompany the requisition.

(*d*) The dimensions and material of brushes for motors and generators should be furnished, and if flexible wire lead forms a part of the brush desired, the word "brushes" in the item should be followed by the phrase "with pig tails." The name of the manufacturer of the apparatus with which the brush is to be used should be given, also the size and manufacturer's serial number of the apparatus with which the brush is to be used.

Example:

4 brushes (one set), carbon, $\frac{3}{16}$" x 1" x 2", for motor end of B. C., $\frac{1}{4}$ kw., motor generator No. 3421.

2 brushes, with pig tail (one set), carbon, $\frac{1}{4}$" x 1" x $1\frac{1}{2}$", for generator end of N. G., $\frac{1}{2}$ kw., motor generator No. 6415.

(*e*) A full description of all wire furnished by the Signal Corps, together with proper designation of each of the various types will be found in Chapter VIII of this Manual.

Example:

2 wire, buzzer, miles.
300 wire, fixture, 40 mils, feet.
200 wire, weather-proof, 128 mils, feet.

(*f*) In listing fuses, the Signal Corps type number and the ampere rating should be given. The Signal Corps type number may be determined by referring to Chapter VIII of this Manual. If fuses desired do not correspond with any of the Signal Corps types, the name of manufacturer of apparatus with which it is to be used, the ampere rating desired, and if practicable, a sample should be furnished.

Example:

10 fuses, type 3, 20 ampere.
20 fuses, type 9, 1 ampere.
50 fuses, 1 ampere, for G. W. common batty. telephone switchboard, sample attached.
20 fuses, 5 amp., for Coke 5–8 can terminal.

(*g*) In entering items of screw anchors, the gauge size of the screw to be used with the anchor and the length of anchors desired should be shown.

Example:

100 screw anchors for No. 10 screws, 1".

(*h*) Either a sketch or principal dimensions of toggles requisitioned should be submitted.

Example:

50 toggles, bolt,=$\frac{1}{8}$" x approx. 3"; cross piece $2\frac{1}{2}$" long.

(*i*) Items of switches should show type (knife or snap) and ampere rating. Items of snap switches should also show whether double pole, single pole, or three way. Items of knife switches should also show whether double pole, single pole, or triple pole, and whether double or single throw. If fused switches are desired it should be so stated.

Example:

2 switches, snap, 10 ampere, D. P.
1 switch, knife, 15 ampere, S. P. D. T.

When knife switches, without bases, for mounting on switchboards, are desired, reference should be made to either Signal Corps drawing 381 E–1 or Signal Corps drawing 382 E–1.

(*j*) Where heat coils are listed, the name of the manufacturer or a sample should be furnished.

Example:

50 heat coils, W. R. Growler.
100 heat coils, sample attached.

(*k*) The great variety of cords used with apparatus supplied by the Signal Corps makes furnishing of satisfactory renewals an extremely difficult one. An effort has recently been made to standardize all cords and cord terminals, and it is believed that those entering renewals on requisitions will find the Signal Corps number of cord desired by referring to chapter 8. It is intended that in the future purchase of apparatus utilizing cords, that manufacturers will be required to select cords to be furnished from drawings in accordance with cord illustrations shown in chapter 8. If possible, cords should be designated by number only. If this is impossible a sample should be submitted.

Example:

6 cords, No. 4.
4 cords, No. 5.
8 cords for obsolete distributing switchboard, as per sample inclosed.

(*l*) In submitting requisition for cable to be used in extension of systems it is desirable to have the necessary lengths entered, as a record of short lengths of serviceable cable is kept in the office of the Chief Signal Officer of the Army and such information results in the issue of lengths that otherwise take up valuable room at supply depots. If the cable is to be trenched it should be so stated.

Example:

800 feet cable, type 213, lengths 350–220–230.
325 feet cable, type 401, length 325.
1,200 feet cable, type 217, trenched.

CARE OF POST TELEPHONE AND SMALL ARMS TARGET RANGE SIGNALING SYSTEMS.

General Orders No. 90, 1910, which pertain to the maintenance of post telephone and small arms target range signaling systems, is entered below for the guidance of all concerned.

The following instructions for the operation, maintenance, and care of post-telephone systems and the buzzer and communication systems of target ranges installed by the Signal Corps are published:

1. The route and location of duct lines and trenched cables on posts and other military reservations will be carefully recorded, and copies of these records furnished to the respective post quartermasters. Officers in charge of construction will in all cases see that no excavating or trenching is done on any post, or other military reservation, without previously ascertaining the location of the cables and ducts installed thereat and determining that these will not be injured by the contemplated work.

2. It will be the duty of the officer responsible for Signal Corps property to see that the cables are properly trenched and that the manholes and outlets are at all times properly covered with soil to the extent intended. Heavy rains or other causes may expose any of these, and thereby subject them to damage. The outlet case pipes will be kept in their original position by maintaining the soil about them in a firm condition. The manholes are to be covered with 6 inches of soil, and no cable or conduit is intended to be nearer than 18 inches to the surface. If any cables are injured by exposure, immedi-

ate steps will be taken to repair them, or if it is impossible to do this, temporary steps will be taken to prevent further injury, and report made through proper channels to the Department Signal Officer.

3. The greatest care will be exercised in handling lead-covered cables, as the paper which forms the insulation of the core takes up moisture very readily, in which event the cable rapidly becomes unserviceable.

4. Underground conduit systems at posts will be connected when practicable to the post drainage system, and underground conduit systems on target ranges will also be provided with adequate drainage. It is necessary to keep surface water from draining into outlet case pipes, as the outlet itself is not intended to withstand constant submerging.

5. To insure that the target range equipment is complete and in a condition to give satisfactory service for the target season, the officer responsible for this equipment will see that the material is reinstalled and connected and a thorough test made of all the equipment one month or more before the commencement of the target-practice season. If any material proves defective an immediate report will be made to the Department Signal Officer, in which the nature of any defect will be fully stated, so that the material and labor necessary for its correction may be provided before the opening of the practice season.

6. At the end of the practice season all buzzers, strap keys, annunciators, master switches, and telephones which might be stolen or become damaged by exposure will be removed from their points of installation to the storehouse.

7. Doors of cable or distributing boxes placed outside of buildings or on poles will be kept closed at all times when not in use.

8. All aerial cables will be protected by fuses so that lightning or other foreign electrical currents may not enter the cable under any circumstances. Particular care will be taken that these fuses are in serviceable condition at all times.

INSPECTION OF POST TELEPHONE AND SMALL ARMS TARGET RANGE SIGNALING SYSTEMS.

An extract of G. O. 5, W. D., 1913, follows:

The systems at interior posts will be inspected twice annually by a competent inspector having technical knowledge of magneto and common battery systems, these inspections to be made, if practicable, during the two months prior to July 1 and January 1 of each year.

The report covering these inspections will be prepared in triplicate on Signal Corps forms Nos. 209 and 211, one copy to be retained for the files of the signal officer of the post, and the other two forwarded, through military channels, for the files of the department signal officer of the Territorial division concerned and the Chief Signal Officer of the Army.

Department signal officers of the Territorial divisions will apply for the necessary orders to have the above-mentioned inspections made.

MAINTENANCE TEST.

In the maintenance of any electrical system, especially where underground or aerial cable is involved, it is advisable to occasionally ascertain the insulation resistance of the circuits.

With the important fire-control systems at our seacoast defenses, it is required that this action be taken once a month, and, although it is not required for post-telephone and small-arms target-range systems at interior posts, it is advisable to make an occasional test incident to the general maintenance of the systems. By this means a partial fault, which in time might result in several circuits becoming inoperative, may be detected.

There are several methods of making the test, the quickest and simplest being with an instrument termed "megger." The Signal Corps has a limited number of these instruments, and, although they are not regularly issued for the purpose, department signal officers usually have one that can be furnished temporarily.

Prior to making this test, the lines should be tested by operating the apparatus connected thereto, and any defects, however trifling, should be noted.

The megger.—The megger shown in figure 10–1 is a direct reading instrument, the type usually furnished having a scale 0–5 megohms.

Current for its operation is obtained by means of a hand-driven generator forming a part of the instrument. In revolving the armature the revolutions per minute should be increased until the crank tends to slip. The slipping effect is caused by a mechanical governor which is intended to maintain a constant speed.

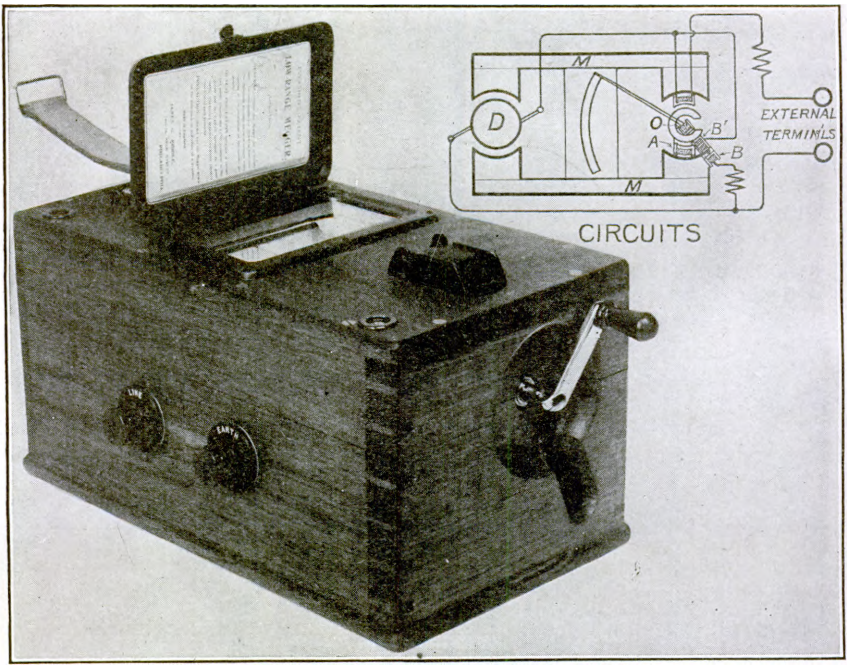


Fig. 10–1.—MEGGER.

The test consists of measuring, to limit fixed by instrument used, the insulation between each conductor of the system and ground. It is not intended that the lines shall be disconnected either at instruments or at cable terminals. An exception to this is made in testing lines of a post-telephone system. These lines are ordinarily tested at the lightning-arrester strip, where, by insertion of a special plug, circuit to telephone switchboard is disconnected and outgoing line is connected to ground through the testing instrument.

Care should be taken not to be misled into believing line wire or cable is defective when low insulation is due to leakage between carbons of lightning arresters. When power lines are tested, switches by which the circuits are controlled should be opened.

In making the tests with megger attach a wire to binding post of megger marked "ground," connecting other end of wire securely to sheath of cable being tested. Attach a well-insulated wire to the remaining binding post of the megger for connection to lines to be tested, and be sure that the instrument is well insulated from earth.

Revolve generator crank handle, increasing speed of rotation until crank tends to slip, and with test wire make contact with lines to be tested. With lines in good condition, rapid progress can be made, as it is only necessary to touch forcibly each line, going from one to another in rapid succession.

The maintenance test can be made with a voltmeter. Sufficient number of dry cells should be used to obtain nearly maximum scale reading. A special voltmeter having a 100,000 ohm coil was originally furnished for making maintenance tests. This voltmeter is termed "post testing voltmeter" and is shown in figure 10–2. It will be noted that specific value of insulation can not be

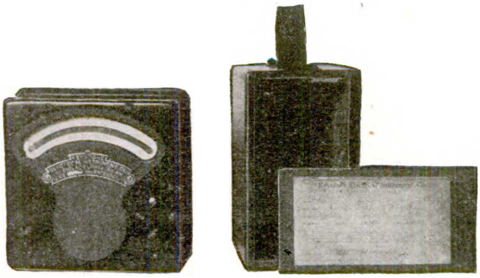


Fig. 10–2—VOLTMETER, POST TESTING.

obtained unless resistance of voltmeter coil is known and that the higher the resistance of this coil, the higher the value of insulation that can be measured.

If a voltmeter is used in making maintenance test, proceed as follows:

(1) Try the line, for actual operation, and note any and all defects, however trifling.

(2) Connect the + terminal from the battery to the ground, utilizing the sheaths of cable being tested.

Be sure that you have a good ground.

(3) Connect the other outside terminal of the battery to one side of the voltmeter.

(4) Connect a well-insulated testing lead to the remaining terminal of the voltmeter, and see that both the voltmeter and the battery are well insulated from the ground.

(5) Apply the free end of the testing lead to the grounded end of the battery and note the reading, which will be called V and should cover nearly the whole scale of the voltmeter.

(6) Remove the testing lead referred to in 5 from the grounded battery terminal and apply successively to the terminals of the line which is to be tested, the reading being noted. These readings are called V_1.

(7) The actual insulation resistance of this circuit may be determined by the formula:

$$R_1 = \frac{R_g (V - V_1)}{V.}$$

R_1 is the insulation resistance, and R_g is the resistance of the voltmeter coil and circuit, which will be found inside the lid of the case and which varies slightly with individual instruments.

Should any of the short lines employed show an insulation to ground of less than 1 megohm, steps should be taken to ascertain the cause of such condition.

The maintenance test may be applied at any point in a circuit.

Moist atmosphere will cause low reading of the megger and high reading of a post-testing voltmeter, due to increased surface leakage, and tests will ordinarily be made when the atmosphere is comparatively free of moisture.

If it is thought that serious leakage occurs when atmosphere is comparatively moist, the difficulty should be remedied and special tests should be made during the damp period to determine this question.

If condition cited in preceding paragraph is found to exist, disconnection of instruments or terminal boxes will usually locate the leak; but it is necessary that any leakage which may develop be corrected whether it be in cable, outlet boxes, switchboard, or in the instruments.

Leakage in the conductors of cables is obviously more serious than any other form of fault and great care should be taken in order to be sure whether faulty conductors exist by eliminating every other source of trouble before reporting the cable defective. It will frequently be found that faulty insulation develops gradually, and that readings from month to month will change in such a way as to make it possible to forecast the working life of a conductor. Arrangements should be made for the correction of such a condition as soon as practicable after it is positively known to exist.

If the foregoing instructions are faithfully followed no absolute interruptions of important lines of communication should occur except from unusual accidents, due to inadvertence.

MAINTENANCE INSPECTION.

At least once a year a maintenance inspection should be made of all apparatus of post telephone and small arms signaling systems, by person or persons designated by local post signal officer.

This inspection consists of an examination of all apparatus of the systems.

Contacts should be examined and made positive, defective telephone mouthpieces replaced, and inefficient instrument circuits repaired before trouble actually occurs.

All external connections to apparatus should be examined for possible corrosion. A strip of paper should be drawn between platinum contacts for the purpose of cleaning them and to make sure the contact is properly made. Only hard-surfaced paper should be used, otherwise paper lint may collect and cause poor or open contact.

Ordinarily, telephone-transmitter shells should not be opened. If trouble arises due to defective buttons the transmitter so affected should be "turned in" to a Signal Corps supply depot for repair and return after having received proper authority for such action. Those making this inspection should be provided with an inspector's pocket kit, described in chapter 8; a telephone receiver; a piece of chamois skin; a portable voltmeter, or portable voltammeter; and a couple of flexible testing cords to which standard spring clips have been attached. One or two dry cells of battery will frequently be found a convenient adjunct for use in testing for identification.

The inspection described above is a matter of commercial routine which is practiced by all commercial companies attempting to give satisfactory service and is absolutely necessary for the prevention of the various serious evils to which the best of electrical installations are liable.

MONTHLY STORAGE-BATTERY REPORT.

This report is forwarded to the Department Signal Officer at the end of each month by the post signal officer.

The report consists of one copy of Signal Corps form 260 duly accomplished for each Signal Corps storage battery attached to the post. Full instructions relative to readings to be taken and recorded are printed on back of the form.

MAINTENANCE OF MOTOR GENERATORS.

The motor generator should be kept covered when not in use. Care in this particular will save the machine from damage by dust. The pneumatic duster, which is supplied to keep the windings clear of copper particles which may be thrown off by the commutators, should be frequently used. Inspect the machine each time before starting, to make sure that it is clean.

Bearings.—The bearings should be filled with the highest grade of dynamo oil to such a height that the surface of the oil comes above the lowest point of the oil rings. If the bearings are too full, oil will be thrown out along the shaft and get into the armature windings and commutator, eventually causing trouble. The oil should be renewed semiannually, and in all cases should be filtered before using again. It is preferred that oil should not be used more than once.

Keep dry and clean.—Keep the machine dry and clean. An accumulation of dust or the dripping of water on any part of it should not be permitted, as it will cause serious trouble in a very short time. The carbon dust from the brushes should not be allowed to accumulate on the brush holders, commutator, or other parts.

By means of a bellows or air blast the set should be thoroughly and frequently blown out, inspection being made each time to determine that all the dust and dirt has been removed. Satisfactory results can not be expected if it is not properly cared for and given attention at frequent intervals. The life of any machine is increased in direct proportion to the attention it receives.

Starting.—Before starting the motor generator set see that all oil wells have a proper amount of oil and that the brushes are properly adjusted. With motor generator set having a direct-current motor, see that the handle of the automatic starting box is in the "stop" position before closing the motor main switch.

After being sure that everything is in readiness, close the motor main switch and start the machine slowly by moving the handle of the automatic starting box step by step toward the "start" position. Be sure that all oil rings revolve freely. The lever of the motor starting box should never be stopped for any length of time until the last step has been reached. When this step has been reached the magnetic holder, the windings of which are in the field circuit, should hold the lever at the last stop. If for any reason the magnetic holder fails to hold the lever, or should it be desired to stop the set before the last step has been reached, the motor main switch should be opened before allowing the starting-box lever to return to the "stop" position.

Regulate the voltage of generator by means of the generator field rheostat.

After putting the generator in circuit, feel all the connections of both machines; if any one is warmer than the other the connection is imperfect and should be cleaned and tightened.

Care should be taken that the field circuit of a motor is not opened, as there is danger of the field coils being punctured. If it becomes necessary to break the field circuit, it should be accomplished slowly, allowing the arc to die out gradually.

Stopping a motor-generator set having a direct-current motor.—The following points should be observed in shutting down the motor-generator set:

Disconnect the leads to the generator by means of switches and circuit breaker on power switchboard; move the generator field rheostat handle to the position showing the lowest voltage obtainable; open motor main switch; be sure that magnetic holder on motor starting box releases the lever and that it returns to the "stop" position. The latter will not occur until the motor generator set slows down perceptibly. This is due to the counter-electro motive force of the set, which continues to energize the magnetic holder after the current is "cut off" from motor.

Never stop the set by releasing the lever of the automatic starting box before opening the main switch, as it is apt to burn the contacts on the starting box and may puncture the insulation of the field windings.

After the set has been stopped, wipe off all oil and dust, and if set is not to be again operated within a reasonable period of time, the canvas case should be placed over it so as to protect the machine from dampness and dust.

Care and attention of commutators.—The commutator surface should be kept clean and smooth. A cloth with a little vaseline may be used to lubricate and clean it, care being taken that it be wiped clean after every treatment.

A rough commutator may be smoothed by using No. 00 sandpaper held against it midway between the brushes while the armature is rotating slowly. Before applying the sandpaper, the brushes should be raised. Never apply emery cloth to a commutator.

A commutator that is eccentric or that has high spots should be turned true. As the turning tool does not leave a sufficiently smooth surface for proper operation, No. 00 sandpaper, mounted on a wooden block fitted to the commutator, should be applied until the surface is perfectly smooth. Inspect the surface to see that the copper has not been burred over from segment to segment, and remove by a scraper any particles of copper which might be found between the segments.

Not infrequently flat spots on the commutator are started by a flash-over developing from an open circuit in windings, or are caused by a dirty commutator. These flat spots passing under the brushes give rise to loud noise and objectionable sparking. They can not be removed properly by sandpaper, and when they develop the commutator should be turned, as described above. The brush holders should be so located on the brush studs that the rings of contact made by the carbons of one set of brush holders overlap those made by the next adjacent set.

Brushes.—The copper plating on the brushes should be kept cut back, so as not to come in contact with the commutator. A small amount of commutator wear will be compensated for in the brush holder by the brush slipping through the holder. Large commutator wear should be compensated for as follows:

Reset the brushes in the following manner: Place a narrow strip of paper around the commutator, having the two ends meet. After removing this paper divide it in as many parts as there are poles, marking each division, then place the strip around the commutator, sticking it on with a little shellac at several points. In this way the proper spacing of the brushes is obtained.

Throw the tension spring back as far as possible. Turn the brush holders on the studs until the brushes are radial. Then clamp the brush holders in this position. The distance between the holders and the commutator surface in all cases should be approximately the same, and should in no case be nearer the commutator than three-sixteenths of an inch. If for any reason the brushes of any stud do not come on the lines of the strip of paper wrapped around the commutator, move that stud so that the brush will come on the line. Now spring the tension spring back into place and apply the proper tension. In all cases such a pressure should be applied as to give approximately 1 pound per square inch of brush contact.

By using a fine grade of sandpaper, the brushes should be sanded to the curvature of the commutator. Cut the sandpaper into strips a trifle wider than one brush. Place this under the brush with the smooth side next to the commutator, then draw the sandpaper back and forth under the brush, keeping it against the commutator, so that the brush will have the curvature of the commutator. End the sanding process by drawing the paper under the brush holder several times in the direction of rotation only. Blow out all carbon dust and wipe off the connections, special care being taken to see that the commutator is cleaned.

Sparking may be caused by—

(*a*) Brushes not being set at the proper place.

(*b*) The brushes not being fitted to the commutator.

(*c*) The brushes not having the proper pressure on the commutator.

(*d*) Some brushes having excessive pressure, and thus taking more than their share of the current.

(*e*) The brushes being burned on the ends, due to excessive overloads having occurred.

(*f*) A rough commutator.

(*g*) A high, low, or loose commutator bar.

(*h*) High mica.

(*i*) Oily or dirty commutator.

(*j*) Open circuit in the armature winding or loose connections between the armature conductors and the commutator tangs.

Hot or glowing brushes are due to excessive current density at the brush contact surface, caused by overloads, incorrect brush position, dirty commutator, or the picking up of copper. The picking up of copper embeds in the surface of the brush small particles of copper, thus causing a low resistance path between the brush and the commutator, and permitting a heavy flow of current at this point, thus developing glowing brushes. This difficulty may be removed by drawing a piece of fine sandpaper across the contact surface of the brush.

Overheating of the commutator may be due to—

(*a*) Overloads.

(*b*) Excessive brush pressure.

(*c*) Sparking. (See general subject "Sparking.")

Overheating of bearings may be due to—

(*a*) Defective alignment.

(*b*) Failure of oil rings to revolve.

(*c*) Rough bearing surfaces.

(*d*) Bent shaft.

(*e*) Not enough oil.

(*f*) Poor grade of oil.

(*g*) End thrust, due to improper leveling.

(*h*) Large unbalanced magnetic pull, due to the armature not being central with the frame; generally resulting from excessive journal wear.

Throwing or leaking of oil is frequently caused by—

(*a*) The oil being too high in the bearings.

(*b*) The plug which is screwed into the oil well drain not being tight.

(*c*) Shaft not being level.

Excessive field heating.—If one of the field coils is warmer than the others the trouble will usually be found to be a short circuit. This may be detected by taking the voltage drop across the terminals of each individual coil.

An unloaded motor generator should start when the lever of the motor starting box is in contact with the second or third segment. If this does not happen, the trouble may be due to an open circuit in the field or armature windings, in the starting box, or undue friction in the set.

While the foregoing pertains principally to motor generator sets with direct-current motors, it applies to motor generator set having alternating-current motors, except that with the sizes usually installed by the Signal Corps the motor is started by merely closing a D. P. S. T. knife switch, no auxiliary starting apparatus being necessary.

POWER SWITCHBOARD MAINTENANCE.

All switch parts should be kept bright and clean, and care should be taken to see that all nuts are tight and that no corrosion exists at the contacts.

The voltmeter switch should be inspected frequently, to see that all contacts are positive. Particular attention is invited to the necessity for regular inspection of all connections in the rear of these switchboards, in order that trouble which might arise from loosening of parts or similar causes may be anticipated. While particular care is taken by the Signal Corps to avoid the possibility of the corrosion of terminals, due to the use of soldering salts and to other causes, it is well to examine the lugs frequently during the first year's operation, since trouble from this cause may occur. It is pointed out that a high resistance, such as might be caused by a defective lug in the circuit of the telephone storage battery, may be the cause of cross-talk.

Separate fuses for all circuits should be kept on hand in ample quantity, and if at any time, through a series of accidents, a number of fuses have been blown and the reserve supply becomes low, special requisition should be sent in without delay, since only under conditions of grave emergency should inclosed fuse terminals be bridged by an open wire link. If this must be done, connection should be made in the rear of the board. When such a fuse is blown, the switchboard is likely to be defaced in a manner which is beyond remedy, aside from the possible damage to the terminals. It is intended that the supply of fuses should be of sufficient magnitude to make such a contingency extremely unlikely.

DRY BATTERIES.

As stated in chapter 1, all cells furnished by the Signal Corps bear the date of manufacture, and no cell except the reserve type should be installed for serious work that is more than 18 months old, unless test with the ammeter and voltmeter shows that it has a voltage of at least 1 or that the ampere reading will be at least 2.

The cells should be stored where the temperature is moderate, dry, and even. When installed, care should be taken to keep the cardboard covers as dry as possible; also to keep the cells separated from each other by a slight air space.

TOOLS FOR MAINTENANCE PURPOSES.

Tool kits and line construction tools appropriate with size and nature of systems will be issued for maintenance of post telephone and small-arms target range signaling systems at interior posts.

Signal officers should use careful judgment in the assortment of tools held at a post for this purpose and should take steps to have "turned in" to a Signal Corps supply depot tools that appear to be superfluous.

MAINTENANCE OF FIELD EQUIPMENT.

Buzzer when in constant use.—As soon as possible after the daily drill, each chief of section should examine his service buzzers and test them out for trouble, whether or not they have been in satisfactory condition at the morning drill or not. This must be done to avoid any minor faults, such as loose key, key short-circuiting, broken connections in line and ground circuits, loose connections to receiver and transmitter, etc. This test should be made in conjunction with the circuit through cart, by plugging in one buzzer on the cart, the other to ground through field wire on drums, making certain that the brushes on each drum make good connections to their commutators.

Learn how to attach reserve cells, which may be necessary when Ever Ready cells can not be obtained.

The receiver and transmitter compartment of buzzers issued in the post should be lined with sheepskin by company mechanics. Buzzers manufactured in future will be provided for in this respect.

Wire carts.—When on march lubricate axles daily. When in garrison lubricate twice weekly.

Cart chains and clutches should be thoroughly cleaned at least once per week. When cleaning chains replace loose or broken cotter pins.

Annually, or semiannually, the wire carts should be taken apart, thoroughly cleaned, and examined for minor faults that will develop. They should be repainted while taken down, and spare parts should be substituted for those badly worn.

In garrison the carts should be parked in sheds such as Field Artillery use. If it is impossible to shelter the carts in the field, the cart paulins should be spread over carts and secured to tongue, mogul springs, and wheels.

If, due to any cause, the field wire has been reeled up on the drums in poor shape, it should be rewound in a shipshape manner, as otherwise it may be so loose as to wrap itself around the cart axle at the next drill.

Cart chains of obsolete type wire carts.—When in constant use wipe off chains with a rag and then apply graphite preparation at least every third day and oftener if the chains are covered with mud.

The sprocket chains on wire carts should be removed and thoroughly cleaned at least once in three months and more often if constantly in use at maneuvers. After removing the chain, wash off all old grease and accumulated sand, using a stiff brush and gasoline or kerosene. When apparently clean, coil the chain in a pan or bucket, covering it with kerosene or gasoline and allow it to stand for several hours if time will permit. If the chain has been cleaned in kerosene, it should finally be rinsed with gasoline, which will then evaporate in a few minutes, leaving the chain clean and dry. Next prepare a lubricant consisting of the following ingredients: Ten parts of the best beef tallow, two parts of heavy oil, and one part of powdered graphite; these ingredients to be heated in a heavy pan sufficiently for the lubricant to flow freely, but not enough heat to draw the temper of the steel. The chain should be coiled in the pan and allowed to remain in the warm lubricant for at least half an hour. This process insures that the lubricant will penetrate every part of the chain, including the inside bearing surfaces of the bushings and rollers.

When the chain has been removed for any reason it should be replaced with the same side toward the sprocket, so that it will run in the same direction as before removal.

Keep pairs of sprockets in perfect alignment.

Wire pikes.—Examine daily the hooks on wire pikes in use and replace those badly worn. Worn hooks tear insulation from field wire, and are frequently jerked from the hand.

Field wire.—When field wire on which the insulation is defective is used on damp ground, moisture causes the wire to rust and break easily. Keep the insulation repaired daily by use of tape.

Leather.—Do not experiment with the preservation of leather. Obtain and follow strictly the instructions issued by the Ordnance Department for cleaning and preserving leather. Leather is often ruined by use of too much oil.

CHAPTER 11.

LONG SUBMARINE CABLES; SUBMARINE TELEGRAPHY; TESTS OF SUBMARINE CABLES.

The construction, characteristics, and manner of splicing submarine cable employing India-rubber compound as an insulating medium, are described in chapter 4 of this manual, consequently it will not be repeated in this chapter because what has been stated in this connection applies also to long submarine cables.

It is believed that the Signal Corps laid the first long submarine cable that had rubber compound for insulation instead of gutta-percha. The cables referred to are the submarine cables of the Washington-Alaska Military Cable and Telegraph System, the longest single stretch of which is between Seattle and Sitka, approximately 1,085 miles. This cable has been in use over 11 years, the service it has rendered being satisfactory.

With the long trans-Atlantic cables gutta-percha is employed as the insulating medium instead of rubber compound described in chapter 4. Gutta-percha has two important characteristics which recommend it for such cables, one is that the deteriorating effect is less than rubber compound provided it is kept constantly submerged, and the other is that it will better withstand the enormous pressure to which a cable is subjected in very deep water. With some of these cables each insulated conductor is wrapped with a brass ribbon, the gutta-percha being first covered with a serving of tape or spun thread. In other respects the cable is constructed in accordance with description in chapter 4. The brass ribbon has proved effective where trouble has been occasioned by the toredo, a submarine boring animal. This little pest, which exists in the Atlantic Ocean and eastern seas, forces itself between the steel armor wires and bores through insulation to conductor, thereby causing a ground or at least a heavy leak.

SPLICING GUTTA-PERCHA INSULATION CABLE.

In splicing cable with gutta-percha insulation, the armor and conductor are treated as described in chapter 4, but the gutta-percha is treated quite differently. Gutta-percha is the sap of the gutta tree, a different species of tree from that from which India rubber is procured. In splicing cable the gutta-percha conductor covering is treated as follows:

The ends of the core should be pared off after the conductor has been spliced and soldered, as the exposed surfaces are apt to be affected by the heat used in soldering joint in conductor. Next clean gutta-percha ends and exposed conductor by wiping with a clean rag soaked in naphtha. Gently warm conductor by means of flame of spirit lamp, great care being taken to not burn or injure the gutta-percha. A stick of Chatterton compound which has been warmed while the above operation was in process is now rubbed over the conductor and that which adheres to conductor is smoothed over to a thin layer by means of a warmed iron. The spirit lamp is then used to warm evenly and slowly the gutta-percha for about 2 inches on each side of the jointed conductor. When sufficiently warmed the two ends are gradually drawn toward each other (by means of the fingers, which should be slightly moistened to prevent sticking) until about one-half inch apart. By the same process one end is then drawn down to a thin film and the other drawn over so as to lap over the former. In drawing the gutta-percha the conductor should be revolved backwards and forwards between the fingers to insure drawing evenly.

The joint in the gutta-percha is then kneaded together with the finger and thumb and smoothed down with a warm iron. The joint thus far completed is then allowed to cool. After cooling it is roughened with a knife and then slightly warmed with a spirit lamp preparatory to treating lightly with Chatterton compound for adhesive purposes. After treating with Chatterton compound the joint is covered with a thin sheet of gutta-percha which has been warmed. This covering is kneaded into place with finger and thumb and smoothed with warm iron. Another layer of sheet gutta-percha is similarly placed after first layer has been treated with Chatterton compound. The latter layer should extend approximately 1 inch beyond the first layer on each end of joint. In applying the sheet gutta-percha great care should be exercised to work out all air between layers. The gutta-percha joint completed, it should be thoroughly cooled by pouring cold water over it and then allowing it to stand in cool air for a reasonable period of time. The joint should then be tested, and if satisfactory, jute or thread servings and armor replaced, as described in chapter 4 of this manual.

LAYING SUBMARINE CABLE.

In laying a long submarine cable it is ordinarily paid out over a sheave at stern of vessel, but in swift currents of coast waters the Signal Corps has found it more satisfactory to pay the cable out over sheaves located in the bow. In deep water where the cable will sink without danger of coming in contact with the propellers it is paid out over the "bow sheaves." These sheaves are permanently located in extreme bow of vessel and are 15 inches in diameter (at bottom of groove) on the cable ship *Cyrus W. Field.* If the water is quite shallow so that cable will extend more or less horizontally, it is run from reel over a sheave 20 inches in diameter, located at end of a boom, the boom being at right angles to ship's length and extending over ship's side from the foremast. With the boom and cable on upper side of current, the ship will swing away instead of into cable and the course of ship can easily be controlled.

The advantage of paying the cable out over the "bow sheave" or sheave at end of boom is that stern of boat can always be turned in order to head in right direction against any tide or current; and while, no doubt, the cable is bent at a shorter radius than when it is paid out over stern sheaves, in some harbors and coastal waters perfect control of cable ship is of paramount importance. A cable paying out over stern has an effect similar to an anchor made fast to vessel at that point, as a tight cable in this position prevents the stern of vessel from swinging freely in answer to rudder, thus preventing accurate steering. On the open sea on long lines this is not so important, as no swift currents are encountered and sharp turns do not have to be made.

When cable is being laid, electrical measuring instruments are so connected to the cable that should a fault develop it could be detected immediately. Cable ship pay-out machinery is fitted with one or more suitable friction brakes in order that cable or grapnel drag line will not pay out too rapidly and that strain on them may be controlled.

When laying long submarine cables more elaborate apparatus is necessary, because in very deep water the cable is subjected to severe strain when being laid or taken up for repairs and the cable ship should be capable of storing in its tanks or hold many miles of cable. The reader can form an idea of the strain on cable to be encountered when consideration is given the fact that not infrequently cable is located and raised in water 2,500 fathoms (15,000 feet) deep.

In view of the fact that the Signal Corps is sometimes called upon to lay short cables in shallow waters by improvised means, an account of method employed in laying a cable in Laguna de Bay, near Manila, P. I., may prove useful. The cable was coiled in a large casco, or lighter, the coil being oblong (about 24 by 16 feet). Starting on the outside, it was coiled snugly inward to a diameter of about 4 feet, the man guiding it going around in a left-handed direction, the helpers squatted around keeping the coil closed in tightly together as the cable came down from above. A wooden cone was erected in the center to the height the pile was to reach, the edges and corners being well rounded off to prevent the cable catching as it paid out. In coiling inward the cable coils were carried up snugly against each other, and then the cable was carried radially across the lower layer (flake, it is called) and another flake begun at the outer edge. If much cable is to be put on, narrow strips of wood (called feathers) are laid along the piece of cable carried straight across. Close and careful coiling, especially in the lower flakes, is necessary.

Sheaves were lashed in proper places to carry the cable up, first over the center of the cone and then aft. Near the stern the cable passed under a horizontal roller, or "fair lead," and means were provided to press a timber against the cable here to pinch it and put on the necessary friction to prevent its paying out too rapidly. The necessary testing apparatus was installed, and the casco towed by one of the gunboats used on the lake. The end of the cable was carried ashore in two small boats, one buoying it between the casco and the boat nearest shore.

This can be done when distance to shore is short, but where the distance is considerable it is necessary to lash two or more boats together forming a raft, on which sufficient cable is coiled to reach the shore. The raft is towed to the shore by a small steam or gasoline launch, paying out the cable from the raft as it is towed.

Care must be exercised to avoid kinks in the cable. This can always be avoided by placing sufficient strain on the cable to prevent its being perpendicular in the water.

The end ashore having been properly trenched and anchored, paying out was begun. Several helpers were on the cable coils, handing the cable up as it started to rise and looking out that no kinks went up. An average speed of 2½ miles an hour was attained, the water being not over 40 or 50 feet deep. When the end was landed the cable was trenched about 3 feet deep, down to low water. Above high water a short cross trench was dug, a heavy log was buried therein, and a chain lashed to it and the cable. This constituted a "sand anchor" to prevent the end of the cable from being pulled out to sea.

The best way to electrically secure the land end of the cable is to run it into the office and connect the conductor directly with the office switchboard. The next best is to splice the submarine cable to lead-covered underground cable, the latter going to the office.

If the cable landing is far from the office, and the cable must be connected with a land line, the end of the cable should go into a cable hut. This is a small structure in which the cable comes up out of the trench and is secured to the lightning arrester, the land line leading out from there. Great care should be taken in properly securing the cable terminal either in the office or cable hut. Bad insulation or poor connections are too often left there, interfering with the work of the line or vitiating the tests.

GRAPNELS.

In locating cable in deep water an apparatus termed a "grapnel" is employed. These grapnels are of various forms, but all types are equipped with arms projecting from a common spindle. The grapnel, or a series of them, is made fast to a strong line and dragged over the ocean bottom at right angle to route of cable. About 5 fathoms of chain is made fast to end of grapnel and dragged in rear of grapnel, as a means of making it follow a straight course on uneven bottom. In addition a length of chain between grapnel and dragging line is used to prevent chafing of line in advance of grapnel. In deep water a considerable amount of dragging line is in contact with ocean bottom.

DYNAMOMETER.

In deep-sea cable work a most-important apparatus termed "dynamometer" is used for measuring the strain imposed on a cable or a line. While the operation of the instrument is comparatively simple, experience in its use is required before one becomes proficient in determining what is taking place many fathoms below the cable ship.

In dragging a grapnel in connection with bringing a submarine cable to the surface, the dynamometer is used to determine when the cable has been caught by the grapnel. Of course, if the grapnel catches on a coral reef or ledge, the effect is almost the same, but the experienced operator will readily detect that the cable has not been caught. On uneven ocean bottom, where the grapnel leaves a high place, taking some time to again reach bottom, the dynamometer quickly transmits to the experienced operator what is taking place, and more line is rapidly paid out or the ship slowed down.

If the breaking strain of cable is known, it is highly advantageous to know to what strain the cable is being subjected when either the operation of laying or recovering is in progress. The dynamometer furnishes this information continuously.

A few of the most important features of laying and recovering long submarine cables have been entered in the foregoing, but the ground to be covered in any study of this subject is very wide and interesting, and justice can not be rendered it in the limited space available here. For further information the reader is referred to "Submarine Cable Laying and Repairing," by H. D. Wilkinson, M. I. E. E., and "Submarine Telegraphs," by Charles Bright, F. R. S. E.

SUBMARINE TELEGRAPHY.

Due to electrostatic capacity and inductive effect of rubber-insulation cable, approximately 25 miles is the limit of length over which audible conversation can be ordinarily transmitted telephonically. This distance can be greatly increased by what is termed "loading," which means that inductance is assimilated in the circuit at one or more points. While the latter has been accomplished in medium length submarine cables, to date it is impracticable on extremely long cables such as those used for trans-Atlantic communication.

On all cables over 200 miles in length the retardation of the signals becomes so great that Morse apparatus is at a serious disadvantage; consequently some more delicate form of receiving apparatus is necessary. That almost universally adopted is the siphon recorder.

A description will first be given of the operation of submarine cables where the ordinary Morse telegraph apparatus is employed. This description will be followed by a description of the operation of submarine cables where the more sensitive siphon recorder is employed.

SWITCHBOARDS.

If practicable the cable should be terminated at the switchboard.

A special high-insulation switchboard for cable stations is furnished by the Signal Corps and is shown diagrammatically in figure 11–1.

The cable conductor or line to cable hut is connected to the upper left binding post. A revolving copper strip is attached thereto and the base is marked "Instruments," "Free," or "Earth," corresponding to positions of the strip.

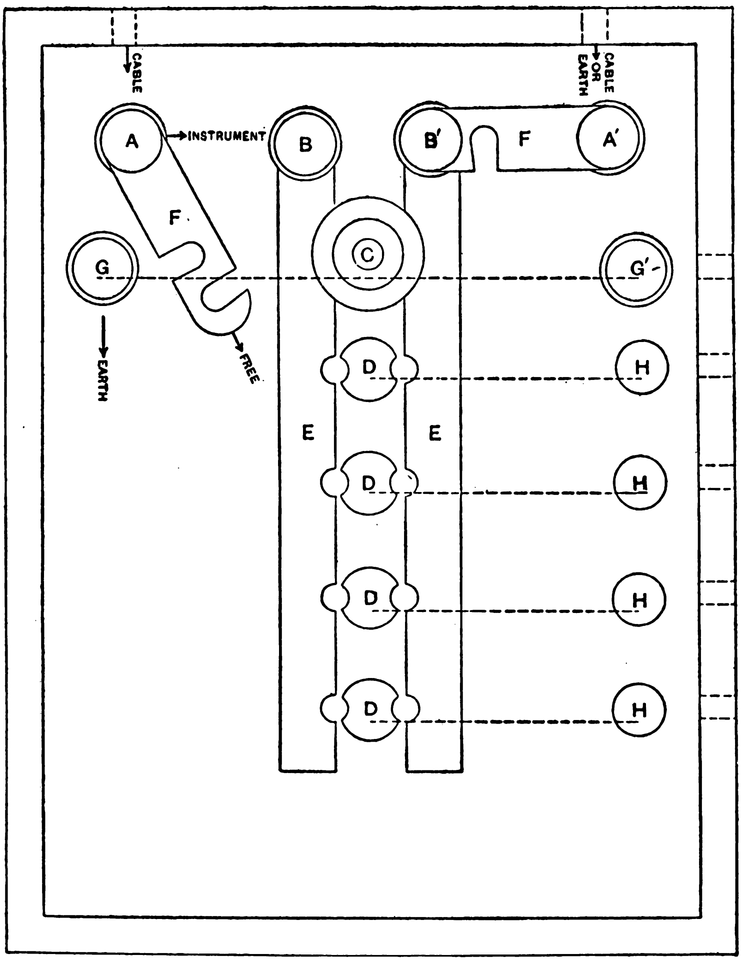


Fig. 11–1.—LONG SUBMARINE CABLE, SWITCHBOARD.

This is a useful arrangement in making tests, to conform to instructions from the ship or distant station.

The wire to ground or to cable leading to the other station (in case this station is a way office) leads to upper right-hand binding post. A disk lightning arrester is connected with a binding post leading to ground wire. The other binding posts are connected with instrument leads in the usual way, and circuits are pegged in as on the land-line switchboards. All openings in the wooden case not occupied by wires should be securely pegged up. The wooden case and glass cover protect the hard-rubber base against dust and moisture. During tests, when insulation must be carefully guarded, a small cup of chloride of calcium may be set in the closed case to absorb all moisture.

LIGHTNING ARRESTERS.

The disk, plate, point, and spiral arresters are all "jump" arresters, when the lightning jumps from plates of metal or carbon, or from points or spiral connected with the line to a carbon or metal plate connected with the ground wire. The metal ones are liable to be fused by a flash and should always be carefully examined to see if the line is accidentally grounded by them. Carbon dust is liable to cause similar trouble in those made of carbon plates separated by thin perforated mica. The fuse lightning arresters, in which a short piece of fusible wire is in circuit with the line, arrest the flash by melting off. This, of course, opens the line, and spare ones should always be ready to replace the burned ones. The delicate ones mounted on mica strips with metal ends need to be especially watched. When the line becomes open or is grounded, the lightning arresters should at once be carefully inspected.

GROUND CONNECTIONS.

These should be made with special care at cable stations.

Where practicable this connection should be made by securely soldering to at least three or four of the armor wires of the cable a copper conductor, 102 mils diameter or larger, leading it in a neat and permanent manner to switchboard. Where plate ground connections are used, the plate should be copper, of at least 5 square feet surface, with the ground wire soldered securely to it.

OFFICE WIRING.

In tropical climates it has been found that the ordinary paraffined office wire is worthless for good insulation. In cable stations nothing should be used but heavily rubber-covered wire. The cable core itself is a type of the insulation which the wire should have. It will pay to put up the wire with extra care, using porcelain cleats and knobs; never fasten a wire with any of the ordinary staples, which in a majority of instances will be banged down on the insulation, cutting into it and causing bad leaks, which are most baffling to find.

INSTRUMENTS FOR CABLE WORKING.

On cables up to 100 miles in length the conditions for successful working do not depart sufficiently from those of land lines to prevent the use of ordinary Morse instruments. The ordinary closed-circuit Morse may be used as long as no incipient fault exists. But with the current constantly on, the least fault in the insulation is rapidly made greater by electrolytic action, and a breakdown soon occurs. For this reason the Signal Corps uses the open-circuit system of Morse telegraph.

A simplified diagram of the open-circuit connections at a station is given in figure 11–2.

As will be seen in diagram, the line comes to the relay, thence to body of key, thence to back contact of key, and to the ground. This is the receiving posi-

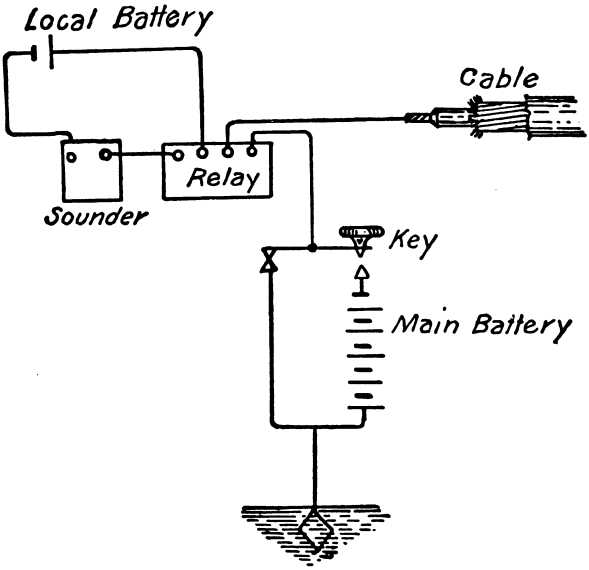


Fig. 11–2.—SUBMARINE CABLES, MORSE OPEN CIRCUIT TELEGRAPHY, CONNECTIONS.

tion, and the current from distant stations will operate the relay. When key is depressed, the back contact is broken and the front contact made; this will cause the home battery to be in the circuit and operate the relays.

Special care must be taken not to screw key so close that both front and back contacts touch. This would short-circuit the battery and speedily ruin it.

The polarized relay has two bobbins or pairs of magnets facing each other, with the armature between them. A permanent magnet supporting the bobbins or in the base gives the cores of the magnets polarity opposite to that of the armature, so that the current coming in one direction tends to send the relay tongue to the front contact, and coming in the other to the back contact. Adjustment is made with top screw, as the relay tongue tends to be more or less strongly held by the permanent magnet on the back contact, corresponding to spring adjustment of the ordinary relay. The screws controlling the magnets seldom need any adjustment. Care should be taken that the armature does not jam against the ends of magnets.

A polarized relay is used for two reasons: First, it is more sensitive and can be worked on less current; second, on account of the large capacity of cables as compared with land lines, the current first charges the cable when the key is depressed, the cable then discharges when key is released, and a momentary current rushes back through the relay. An ordinary relay would give a " kick " corresponding to this, but the polarized relay, responding to the direct current only, is not affected by this momentary discharge current in the opposite direction, and the signals are not " chopped."

46581°—17——29

The key has a back, middle, and front contact, as shown, the battery being put to line only when key is depressed. The battery used is some form of good open-circuit battery like the Gonda, or large-sized dry batteries.

DOUBLE-CURRENT WORKING.

When the cable appreciably exceeds 100 miles in length it begins to work heavily on account of the appreciable length of time it takes for the cable to charge and discharge. A modification of the simple open-circuit method of working, just described, must be made. This is called the double-current method, and in principle consists in connecting an additional main-line battery to the back contact of the key with polarity opposite to the main-line battery connected to front contact. These batteries, by alternately connecting opposite poles to line as the key is up or down, serve to discharge the line much more

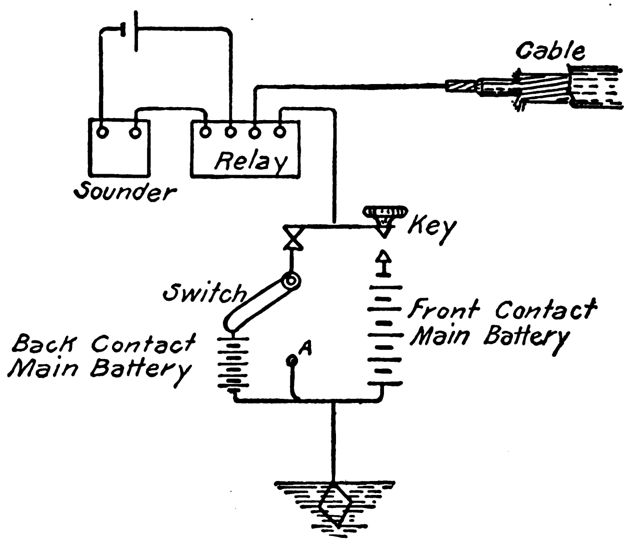


Fig. 11–3.—SUBMARINE CABLES, MORSE DOUBLE CURRENT TELEGRAPHY, CONNECTIONS.

rapidly and greatly increase the speed of working. A simplified diagram of the connections is given in figure 11–3.

The simple change to make it a plain open-circuit set appears when the switch is thrown to *A*. With the key on the back contact, a current flows to line from the + pole of back contact battery. When key is depressed the — pole of the front contact battery is connected to line. The polarized relays are so connected that they close the local circuit with front contact battery to line. Connections for a three-station line for double-current working are shown in figure 11–4.

Without a switch the back contact batteries would soon be run down. As operators are accustomed to closing the key with the ordinary circuit-closer lever, a key is issued by the Signal Corps obviating the use of a separate switch. The connections are so arranged that the customary movements of the switch lever will make the correct connections for the double-current system. Other combinations can be made with this key which is shown in figure 11–5.

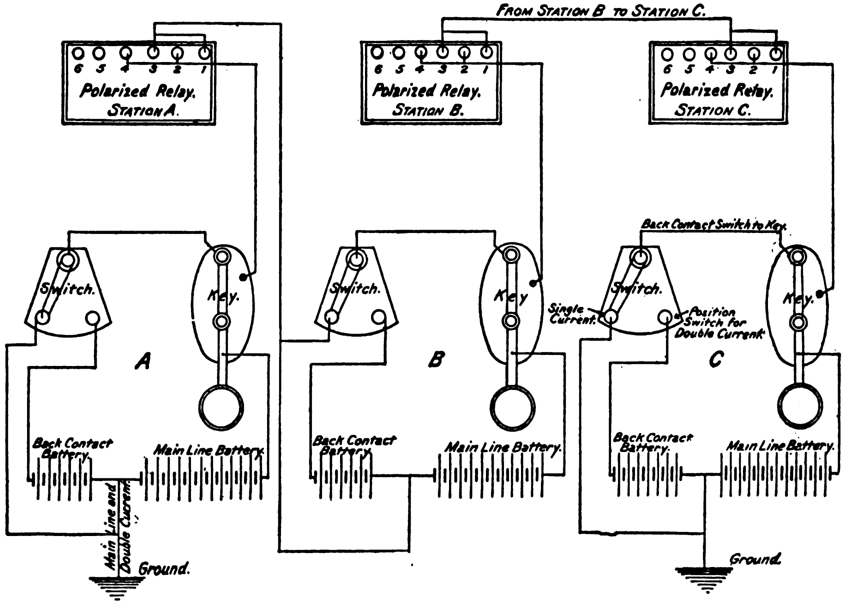


Fig. 11–4.—SUBMARINE CABLES, MORSE DOUBLE CURRENT TELEGRAPHY, 3-STATION CONNECTIONS.

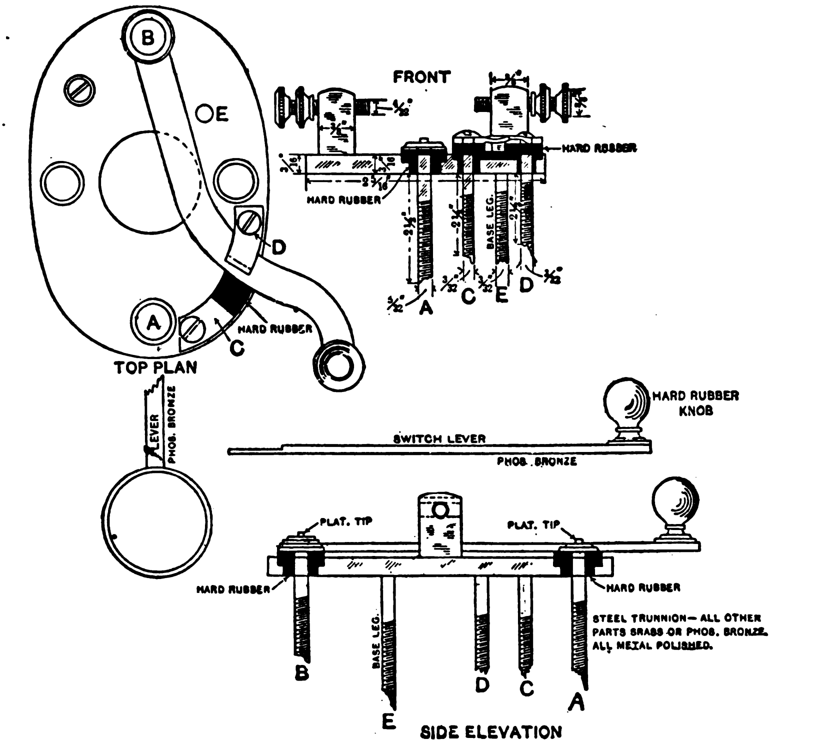


Fig. 11–5.—SUBMARINE CABLES, MORSE DOUBLE CURRENT TELEGRAPHY, KEY USED BY SIGNAL CORPS.

SINGLE-CURRENT OPEN-CIRCUIT REPEATER SETS.

[See fig. 11–6. Fig. 11–7 is a simplified diagram.]

Mounted on a small table top are the following instruments: Two polarized relays, *AA;* two sounders, *BB;* two open-circuit keys, *CC;* two transmitters, *DD;* one double switch, *E.*

The main line and local batteries for each of the lines, the lines themselves, and the earth are connected to the binding posts marked on the table. These connections, especially those of lines and earth, should be made through the switchboard, lightning arresters, etc.

POLARIZED RELAYS.

These are very similar in relation of parts and construction to the square Western Union pattern used heretofore on the Philippine cables, with the addition of a small switch *F* (fig. 11–6) on each, which permits the local to work on either front or back stroke. If the sending comes reversed, throw the switch to the other button.

Adjustment.—The lower adjusting screws on each side should be turned until the magnets are fairly close to the armature, care being taken not to jam them against the armature. The relay tongue can then be caused to fall over to one side or the other, as desired, by the top adjusting screw. The magnetic retraction corresponding to relay spring can thus be made strong or weak, as desired. For repeating, the set works better if the relay tongue has a barely perceptible play.

Before substituting the repeater set for the two office sets find out from each operator at distant ends of both Nos. 1 and 2 lines whether zinc or carbon is connected to the front contact of his key. Suppose No. 1 says zinc. Connect up several cells of battery, put wire from carbon in "earth" binding post of repeater set. Connect two cells at local binding posts of No. 1. Then tapping with wire from zinc on line No. 1 binding post, note if it works the relay No. 1. If not, move the upper adjusting screw until relay tongue just falls over on the other contact, and it should then work it. If your sending comes reversed on the sounder, throw the relay switch *F* (fig. 11–6) onto the other contact.

Proceed in the same way with No. 2, being sure to tap on line No. 2 binding post with the wire coming from same pole of your experimental battery, as reported by distant end of No. 2 as going to line through front contact of key.

Now, having placed the table in position and run the wires from switchboard, batteries, etc., to the proper binding posts, place the switch at "cut" and try to work on, say, No. 1. If you do not succeed, reverse the wires leading to main battery No. 1 binding posts, and this will probably send the current in the right direction to work both your own and the distant relay.

Proceed in the same way with No. 2 before attempting to move the main switch to the "repeat" position.

SOUNDERS.

These should be adjusted with as little play in the lever as is consistent with sufficient loudness.

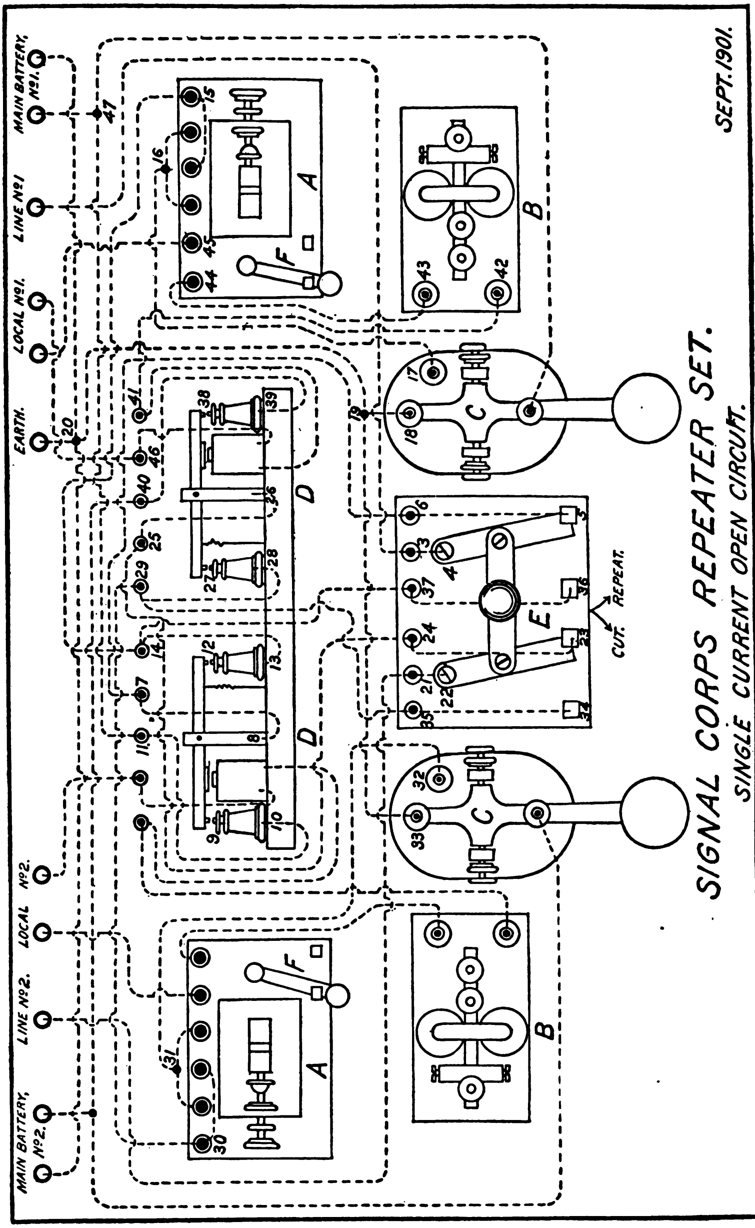
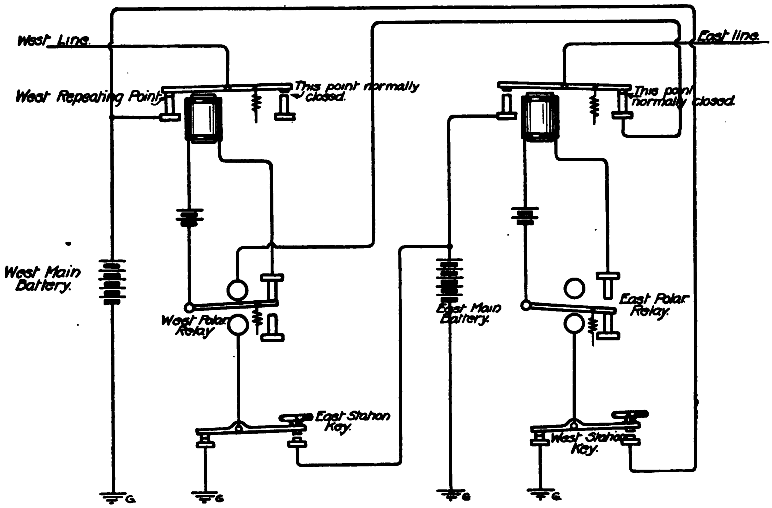


Fig. 11-6.—SUBMARINE CABLES, MORSE TELEGRAPHY, SINGLE CURRENT OPEN CIRCUIT REPEATER SETS.



As shown battery at terminus of East line is connected to line. This closes West polar relay which connects "West main battery" in circuit with West line.

Fig. 11-7.—SUBMARINE CABLES, MORSE TELEGRAPHY, SINGLE CURRENT OPEN CIRCUIT REPEATER SETS, SIMPLIFIED DIAGRAM OF CONNECTIONS.

TRANSMITTERS.

Each of these has a front and back contact, like the keys; in fact, it is an open-circuit key worked by its electro-magnet in the local circuit with the sounder. For good repeating, the lever should have barely a perceptible play. Be careful that the armature does not strike the magnet; this would prevent the "front contact" from being made at the contact points nearest the magnets.

Having made the various adjustments, throw the double switch from "cut" to "repeat." The two lines should then work into each other.

Note that when distant station or key of repeater set is working, say, on line No. 1, only that side of repeater set should be working, and similarly for No. 2.

If operators at distant ends complain that signals are imperfect, note if repeater, relay, and transmitter levers are set to work extremely close, or if the adjustment is not too strong on the relays. Also if the springs in the transmitters are not too strong.

Senders on lines tied together by repeaters should be cautioned that light, jerky sending is particularly hard to get through repeaters well.

DESCRIPTION OF OPERATION OF OPEN-CIRCUIT SINGE-CURRENT REPEATING SET.

[See fig. 11–6.]

First, suppose distant station on line No. 1 is working, the double switch set to "repeat." The current comes in line No. 1 binding post, thence to 3 and 4 to right bar of switch, through contact 5 to 7 and 8 on left transmitter, through lever of transmitter to back contact 12 and 13, through 14 to relay at 15, through relay coils operating the relay tongue, then out at 16 through 17 on key, through body of key to 18, 19, and 20 to earth. The local circuit being closed at relay, the local battery sends in a current through binding posts local No. 1, thence to magnet of transmitter through 46, out at 41, through sounder at 42 and 43, through relay local points at 44 and 45, thence back to local No. 1 battery. When the local current passes through transmitter magnet it closes the front contact. This permits the current of main-line battery No. 2, starting at binding post, coming to transmitter on 40, to front contact 39 and 38 through lever of transmitter to 26, then to 25, to switch contact 23, through 24 to left bar of switch, to 22, 21, and to line No. 2 binding post, out to line, working the instruments in that line. An exactly similar thing happens when an operator in line No. 2 sends a current through his side of the repeater set.

When the repeater station works his key on the No. 1 side, a current comes from No. 1 main-line battery left binding post to the front contact of his key through 47, thence through key lever to body of key, then to relay No. 1 through 17, through relay and out to line No. 1 through 16, 15, 14, 13, 12, 8, 7, 6, 5, 4, 3, to "line No. 1" binding post, and out to line.

Relay No. 1 works its local circuit, causing the transmitter to repeat into line No. 2, as before explained.

When switch is turned to "cut," each key, relay, and the transmitter and sounder in local circuits work independently as two ordinary open-circuit sets.

Two small resistance coils under the board are arranged to shunt the sounder and transmitter magnets of each set. This prevents sparking and sticking at the local relay points.

Notes on Efficient Morse Working of Submarine Cables.

Battery.

The battery power used in working Morse over a submarine cable should be as low as possible, for the protection of the cable itself, as well as for the reduction of the retardation effect of the static capacity of the cable.

The batteries at each station should be inspected frequently and care taken that there is no corrosion at their connections and no creeping of salts and that every connection is good and tight. If possible they should frequently be tested for voltage.

Relays.

Whatever may be the type of relay in use, great care should be taken in making the adjustment that there shall be no stiffness at the pivots or trouble from dirty contacts. Trouble frequently occurs through rust or corrosion at the pivots which makes the sensitiveness of the relay very irregular, requiring more current to operate it at times than the normal amount.

In general, polarized relays are more sensitive than the ordinary 150-ohm relay and should be used wherever possible. In these relays the magnets are drawn back by screws attached to each pair. The sensitivenesss of the relay of this type is increased by drawing back the magnets, but at the same time the strength of the action of the armature is made more feeble. The adjusting screws on top should be so arranged that the armature tongue naturally falls slightly to back contact, the arriving signal pulling it to front contact. In the polarized relay it should be remembered that magnetic action is substituted for the spring, and consequently the amount of *bias*, as it is called, is regulated by the adjustment of the top adjusting screw.

In general, when the two lower screws controlling the magnets are once set to regulate the required amount of sensitiveness they should seldom be changed, the ordinary adjustment for changes in line conditions being made entirely with the top screw.

When the line is worked through condensers at the receiving end (fig. 11–8) the top screw is then so regulated that the armature tends to fall either way indifferently, the motion of the tongue to-and-fro being determined by the positive and negative discharges from condensers produced by the action of the distant key.

The object of placing a condenser in the receiving circuit in this latter method of working is to cut off the action of earth currents, which in the ordinary open-circuit system in some cases make constant changes necessary in the adjustment of the relays. The shunt placed around the condenser should be adjusted as near infinity as is consistent with firm signals, to prevent troubles from earth currents mentioned above. Except at infinity, the use of the shunt permits of giving more or less bias to the relay tongue.

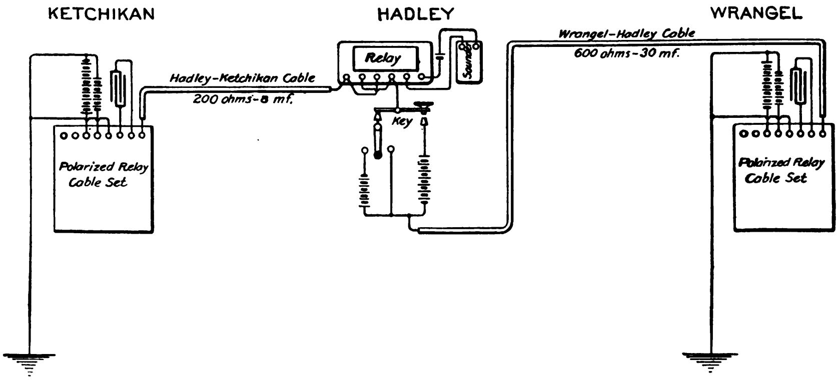


Fig. 11–8.—SUBMARINE CABLES, POLARIZED RELAY SET, CONNECTIONS.

The magnets of the receiving relay, if of the ordinary 150-ohm type, should be adjusted well up, close to the armature, without actually touching it, and the battery gradually reduced until there is no sticking of the signals noticed, with no battery on the line. The spring should be " turned down " completely until the armature falls forward against the front contact, and then again " turned up " until the armature falls against the back contact, and then again " turned up " the least bit more to allow a margin for adjustment. If a relay of the Frier self-polarizing type is used, the attracting magnet should be kept close to the armature, and the other magnet adjusted to get the best effect.

In an open-circuit Morse system on cables when it becomes necessary to pull the magnets of the relay away from the armature, it shows that more battery is being used than is required. This battery, therefore, should be immediately cut down and the magnets adjusted close to the armature, as above mentioned.

PROPER TOUCH TO KEY.

Morse working on cables requires a different touch from that needed on short land lines. Many operators brought up to work on short land lines are inclined to use a nervous, light, and jerky style. This when applied to cable working causes much trouble. The dots come very weak or fail altogether, while the dashes stick, making it extremely difficult to adjust. At times it would seem as if the line or battery were giving trouble, while in reality the fault is in the sending.

The cable operator needs a swinging, solid style, with not a very great difference between the dots and dashes, but with a uniform contact. With such style no difficulty will be experienced in keeping the relay adjusted. The greater static capacity of a cable the greater the effect of irregularities in sending.

The time of charge of a cable should always be taken into consideration, and the sending regulated accordingly.

REPEATERS.

Wherever possible repeaters should be inserted between a land line and a cable instead of working directly through, as the battery is increased on land lines from time to time through various causes, such as weather conditions, bad joints, and connections, etc. By the insertion of repeaters the amount of battery going into the cable is always the same, and the adjustments of the instruments on the cable side will vary but little, if any. The operator at the repeater station should keep his instruments well adjusted to the conditions of the line, making the relay work the repeater heavy or light according to the requirements. Very often the signals seem clear to him, but do not reach the other station properly. The trouble will probably be due to dirty contacts in the repeater. Dust accumulating at the contact points of the sending key, or at the contact points of the repeater, is a common cause of high resistance in a circuit. These points should always be cleaned with crocus cloth, or if very dirty or corroded with a very fine file.

GENERAL NOTES.

If a jar, or rattle, is noticed on the receiving relay it will generally be caused by a loose connection somewhere, unless there is a land line in circuit that is swinging against something.

Before increasing the amount of battery on any cable, the chief operators at each end should consult and try to get at the exact cause of the trouble and report immediately to the officer in charge. The minimum number of cells of main-line battery which will operate a cable efficiently will be determined. After the number is determined, all operators are forbidden to increase the number of cells except by authority of the chief operator, who will report the matter to the officer in charge, so that immediate steps may be taken to remove the cause of the trouble.

A good operator will always know by the "feel" of his relay the condition of the circuit. If the circuit is grounded between stations his home relay will work stronger than usual; the nearer the ground is to his end the stronger the relay will work. If the line is open at the distant end, and an ordinary relay is used, he will get two inductive kicks from the "static" of the cable, one on closing the key and one on opening it. These kicks will be lighter the nearer the disconnection is to his station, as there will be less "static." If he gets no kick the disconnection must be near home. With a polarized relay he will get the click on his relay only when closing his circuit. It should be the duty of every operator to get familiar with this "feeling" of his line by getting the operator at the other end to free the line for a few minutes and then ground it direct without the distant relay being in circuit for a few minutes; he can then put his home relay at a certain adjustment, which he can use for these tests, and note the effect with the distant end open and distant end grounded without the distant relay being in circuit and also with the distant relay in circuit, as it is normally.

Whenever a lightning arrester is used, it should be frequently examined for a "ground" or loose connection. A piece of paper moved back and forth between the ground plate and the line connection will generally remove any dust or foreign substances which may have accumulated there.

In a plug switchboard care should be taken that the plugs are clean and fit snugly in the holes. The holes should be cleaned out frequently, as in certain climates insects find it convenient to nest therein. Sometimes the holes and plugs become corroded or worn irregularly, with the result that the circuit becomes partially or totally disconnected. If a trouble like this occurs it would be well to bridge across with a small piece of wire the connections made by the plugs.

In moving offices from one building to another in isolated places the wiring is often crude and in time causes trouble, and new men make changes from time to time to meet the emergencies that may arise. The operator in charge should make a diagram of the office connections, showing the location of each wire and post it in a prominent place in the office and, when relieved, explain it all in detail to his successor.

The electrical engineer or a thoroughly competent man should visit all stations from time to time and remedy any deficiencies in the conditions. Instruments should be overhauled and properly adjusted, and batteries and wiring gone over thoroughly.

OPERATION OF LONG SUBMARINE CABLES.

As previously stated in this chapter, Morse apparatus is at a serious disadvantage on cables over approximately 200 miles in length, due to retardation of signals occasioned by large electrostatic capacity of such cables, and the siphon recorder, a more delicate form of receiving apparatus, is almost universally used in such instances.

What has been stated relative to wiring at cable stations where Morse apparatus is used applies also to stations where the siphon recorder is installed, and great care should be taken to obtain a high insulation of all wiring and between all apparatus and earth.

SIPHON RECORDERS.

The siphon recorder may be briefly described as a moving coil galvanometer, with a delicate glass siphon attached to the coil in such a way that the motions of the coil are transmitted, very much magnified, to the point of the siphon. One end of this siphon dips into a small ink well, the other end, where the motion is greatest, touching the moving paper tape. This tape is kept moving steadily by means of a small electric, spring, or weight-driven motor. Every motion of the coil is recorded as a deviation in the straight line being drawn on the tape, and signals produced by sending quick impulses from either the positive or negative side of the battery will be recorded as short waves above or below this straight line. To render the siphon more sensitive by reducing its friction against the tape, it is kept in constant and rapid vibration by electromagnetic means.

The construction of the recorder is shown in figures 11–9 and 11–11.

Figure 11–10 shows a simplified diagram of the connections.

Figure 11–9 is the large siphon recorder used generally on the long cables. In the field of the permanent magnet *B* the flat rectangular coil *A* of fine insulated wire is suspended by fine threads above and below. Fine wires connect the recorder coil with the cable circuit.

When current impulses arrive, they deflect the coil, the direction depending upon the polarity of the receiving impulse. These motions are generally very small. The coil is attached by two fine silk threads to a small piece of aluminum, to which is attached the glass siphon *C*. The aluminum piece is itself suspended by a fine horizontal wire. The silk threads from the coil being near the point of suspension of the siphon, every motion of the coil and threads is thus magnified at the lower end of the siphon. The siphon dips at the upper end into the ink well *D* and at its lower end lightly touches the moving tape *E*. This tape is moved forward steadily by the gear wheels *J*, which are driven by a shaft extending back and carrying a pulley which is driven by the motor *H* through a flexible belt.

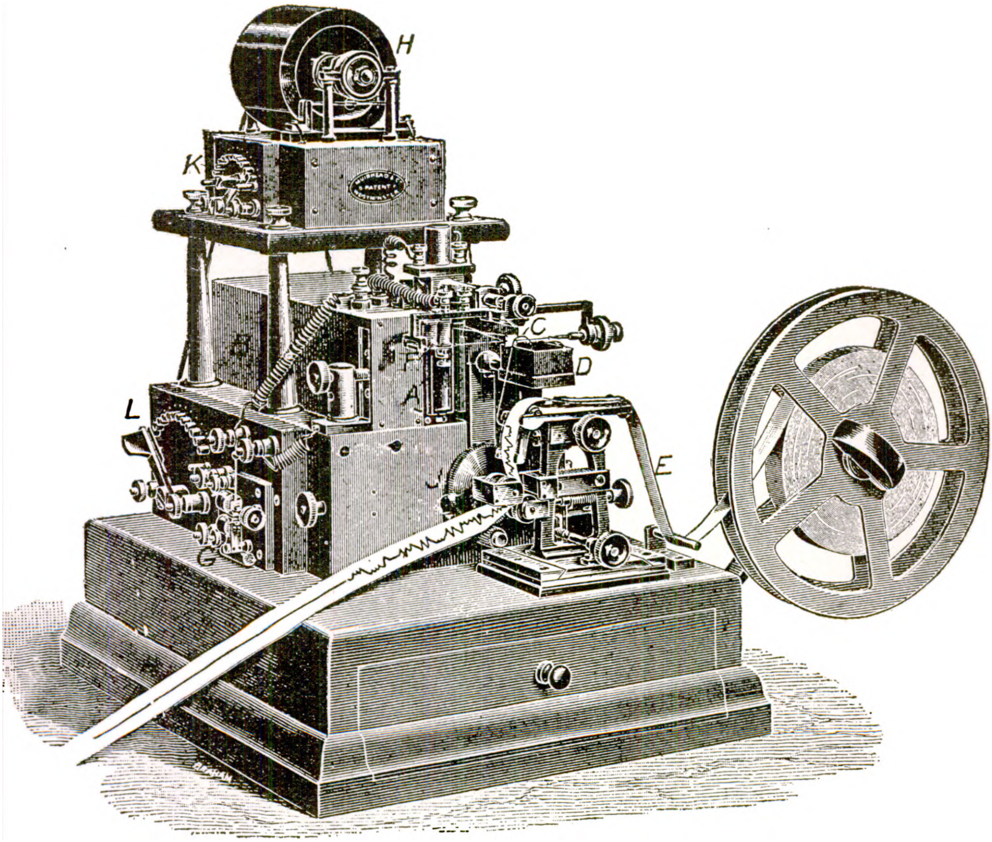


Fig. 11-9.—LONG SUBMARINE CABLES, LARGE SIPHON RECORDER.

To eliminate friction of the siphon on the paper tape, the siphon is kept in vibration by means of a small electromagnet *F*, to the armature of which is attached the horizontal wire carrying the piece of aluminum and the siphon. Through the electromagnet *F* rapid pulsations are sent from the interrupter *G*, which is similar to a small vibrating bell mechanism.

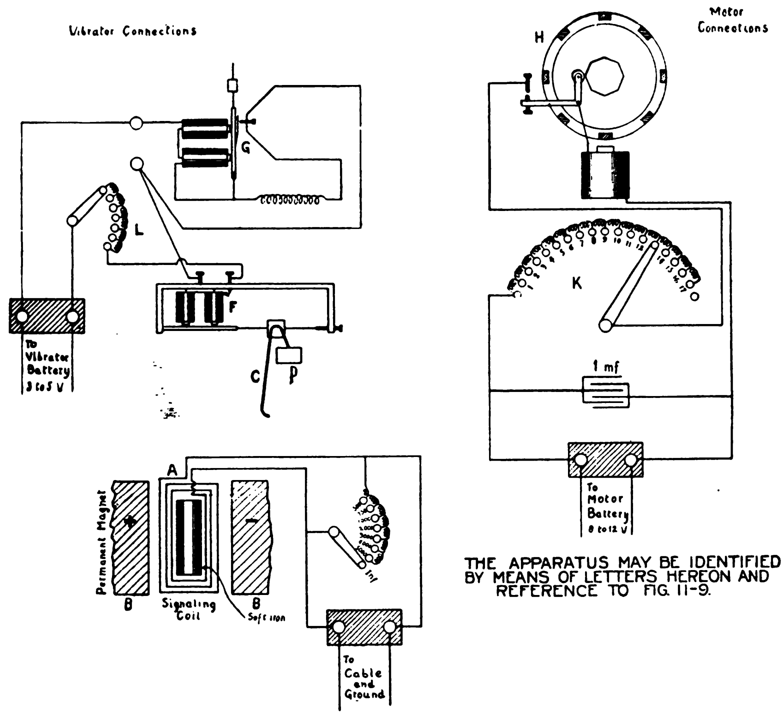


Fig. 11–10.—LONG SUBMARINE CABLES, LARGE SIPHON RECORDER, CONNECTIONS.

The interrupter and vibrator are controlled by a small rheostat *L* being included in their circuit. The speed of the motor is regulated by a rheostat *K*. On the other side of the recorder is an adjustable shunt coil which regulates the proportion of current through the coil *A*, coming from the cable.

The small recorder (fig. 11–11) is used on the shorter cables. It is only about one-fourth as sensitive as the large one just described. In its essential parts it is very similar to the large one, the siphon suspension being somewhat simpler and more compactly arranged.

The permanent magnets of both these recorders have coils wound around them for the purpose of strengthening their magnetism, in case it is weakened, by sending a momentary direct current from some 100-volt source through them. Care must be taken that the current is direct (not alternating) and that it is sent in the proper direction.

The following, on adjustment of the recorder, the vibrator, and motor, is drawn in part from Beginners' Manual of Submarine Cable Testing and Working, by G. M. Baines:

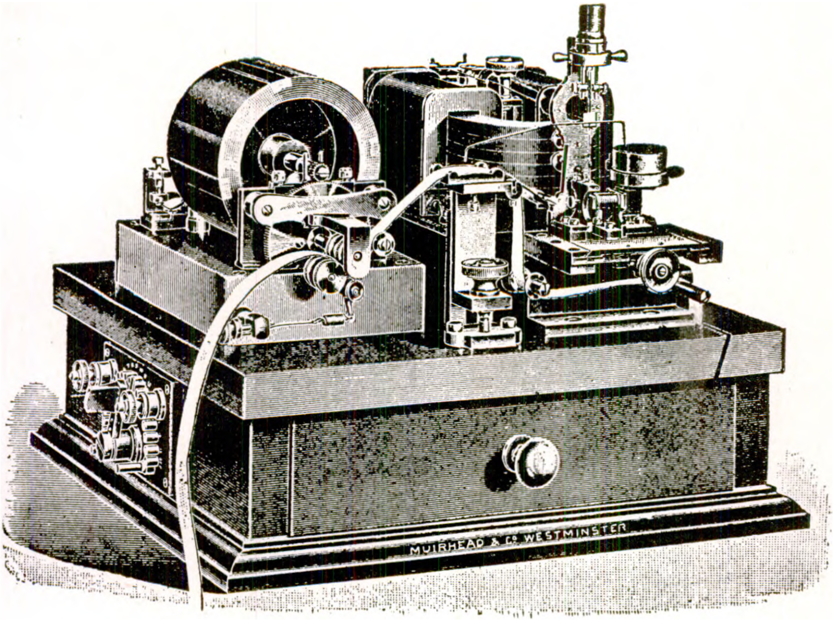


Fig. 11-11.—LONG SUBMARINE CABLES, SMALL SIPHON RECORDER.

ADJUSTMENT OF RECORDER.

The present form of recorder, known as the "Hybrid," is of the permanent magnet type. As it has been found, however, that the magnets lose a proportion of their strength in tropical climates, a winding of insulated copper wire, with a resistance of about 8 ohms, has been provided for them. This arrangement, whence the instrument derives its name, permits of the restoration of the magnetic field strength when it falls below its normal value.

On the supposition, then, that the magnetometer proves the magnetic field to have fallen below 10 Cuff units, a current from an E. M. F. of 100 volts should be applied to the aforementioned coils. For this purpose the ends of the coils have been conveniently brought to terminals on the instrument which are marked, respectively, with the positive and negative signs.

The operation of strengthening the magnetic field is carried out in the following manner:

The positive pole of the battery—preferably secondary cells or dynamo, because for the desired effect a large momentary current is required, therefore the internal resistance must be inconsiderable—is connected to the terminal marked +. To the other terminal should be joined a short, thick wire. The current is applied by three or four momentary contacts between this wire and the negative pole of the battery or dynamo, due care being observed that the operator does not include himself in the circuit.

The "Hybrid" may also be used as an electromagnet recorder by maintaining a battery on the magnet coils. It is intended, however, that it should be employed as a permanent magnet instrument, its field strength being kept at its normal value in the manner indicated.

The double fiber between the signaling coil and the siphon cradle is an improvement upon the old single-fiber attachment. By this new arrangement the full movement of the coil is imparted to the siphon.

The renewal of the double fiber, when necessary, is effected in the following manner:

1. Set the coil square and fix it.
2. Place the bridge piece in its central position.
3. Turn the milled head at the right-hand extremity of the bridge until the siphon cradle hangs perpendicularly.
4. Attach one end of the fiber to the right side of the top of the coil; fix it with the shellac supplied for the purpose; pass it round, or through, the siphon cradle; fix it there and lead it back to the top of the left side of the coil, where it will also be secured.

Great importance is attached to the preservation of the following equidistances:

1. Between the attachment of the fiber ends and the coil center.
2. The two points where the fiber passes through the siphon cradle and the cradle wire.

To obtain the most suitable adjustment of the fibers, first slacken them and set the siphon in an upright position by turning the milled head which holds the cradle wire. Next, tighten the coil fibers, and if the siphon be deflected from the perpendicular bring it back by a slight turn of the milled head carrying the coil suspension. This will square the coil and bring back the siphon to the perpendicular at the same time.

If, on again tightening the coil fibers, the siphon deviates, it will be found that the aforementioned equidistances have not been preserved.

A broken coil suspension admits of easy repair.

Thread a piece of silk through the aluminum attachment at the top of the coil, tie the ends in a loop, and pass them up through the coil cap over the small pulley above it.

A proper adjustment of the signal coil is a matter of utmost importance for securing the double result of maximum signal speed and definition. Experiment has demonstrated that for rapid speeds better defined signals are obtained by discarding the shunt and tightening the coil suspension. By this means a quicker periodic movement is given to the coil. The shunt exercises a damping effect on the coil, rounding the signals in such a manner as to render them unreadable at high speeds.

This periodic movement of the coil would also require attention if, for instance, it were found necessary to change over an electrically long cable to an instrument adjusted for a short one, or vice versa. For the long cable, with a slower signaling speed, a larger periodic movement of the coil would be required to give a sufficient amplitude to the signals.

With regard to the adjustment of the vibrator, the screw and weight on the interrupter *G*, figure 11–12, is the most important factor, and should claim first attention if a failure of ink occur. For the vibration of a long, fine siphon the weight will need a higher position on the make-and-break rod than would be required for a coarse tube. The movement of the vibrator armature should be so regulated as to be nearly invisible. Variation in the thickness of the ink flow may often be obtained by altering the rheostat resistance *L*.

MUIRHEAD'S VIBRATOR.

Figure 11–12 explains the connections of this apparatus. A battery of from 3 to 5 volts, with low internal resistance, is required to properly operate it. Four Edison primary cells, type V or their equivalent, will suffice. Resistance *L* permits the regulation of the current as desired. The action and use of the instrument are too well known to need a lengthy description. It will be found

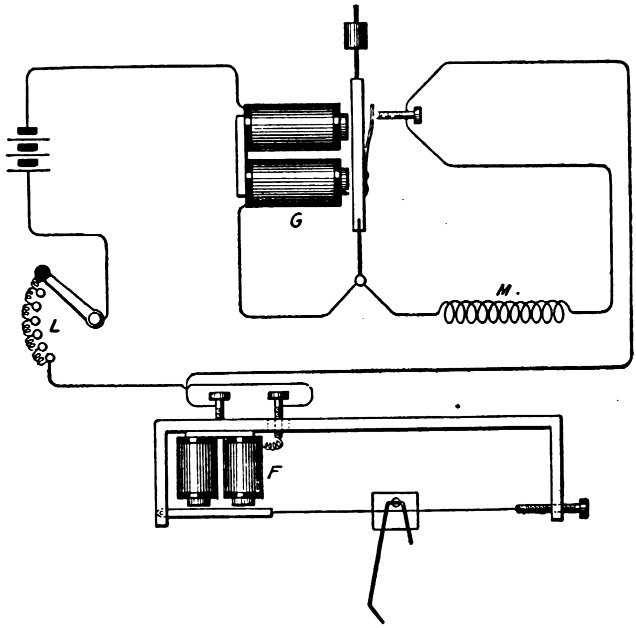


Fig. 11–12.—LONG SUBMARINE CABLES, SIPHON RECORDER, MUIRHEAD VIBRATOR. CIRCUITS.

that the best result is obtained when the interrupter *G* works almost silently. Fine siphons are also recommended as being susceptible of greater vibration than coarse ones, with a consequent reduction of friction between the siphon point and the paper. The spark coil connected between the make-and-break contacts is indicated as *M* in the plan below. The resistances of the interrupter *G* and vibrator *F* coils are about 10 ohms per pair.

THE MOTOR.

The present form of recorder motor is a development of the original type introduced by Lord Kelvin. A cam is suitably adjusted to allow the current from the driving battery to pass at the proper points, in sequence, through the coils of the fixed electromagnet below the revolving drum. A set of resistances *K*, figure 11–9, on the motor base can be introduced into the circuit of the battery and the electromagnet coils for the regulation of the speed.

Soft-iron bars, disposed at equal distances from each other, are fixed longitudinally on the surface of the rotating brass cylinder, through the center of which passes the axle upon which the whole revolves.

At the instant a bar, attracted by the electromagnet, arrives opposite the core of the latter the battery is cut off by the cam. The momentum carries the bar past and brings the next near the core of the electromagnet. The cam again closes the current, giving another impulse to the drum, and so on. The result of this series of operations is a continuous revolution of the drum.

For operating the recorder motor a battery of from 6 to 12 volts with low internal resistance and a large ampere-hour output is required. Six to twelve Edison primary type V cells or their equivalent will prove satisfactory.

OPERATION OF MOTOR BY ELECTRIC-LIGHT CURRENT.

Where the office is provided with electric lights fed by direct current from 110-volt circuits the table-lamp circuit can be utilized in place of a battery, as shown in figure 11–13 for operating the motor.

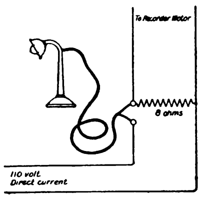


Fig. 11–13.—LONG SUBMARINE CABLES, SIPHON RECORDER, TO OPERATE MOTOR FROM ELECTRIC LIGHTING CIRCUIT.

The 8-ohm resistance coil, made up of sufficiently large wire not to heat with 1 ampere, is in circuit with the 32-candlepower table lamp. This coil is shunted by wires from the motor, as shown. An E. M. F. of approximately 8 is obtained at the motor terminals by this arrangement.

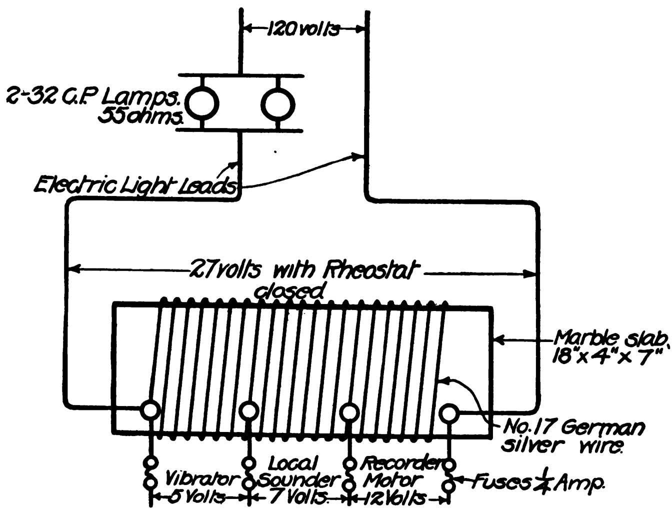


Fig. 11–14.—LONG SUBMARINE CABLES, CURRENT SUPPLY AT SEATTLE TERMINUS OF SEATTLE-SITKA CABLE.

Figure 11–14 shows another method. The latter is now being used in the Signal Corps cable office at Seattle, and results are entirely satisfactory. The coil may be extended to supply additional instruments, such as cable transmitters, with current.

The motor and vibrator should not be driven by the same battery on account of the constant variation in the potential of the latter. Say the motor battery has an E. M. F. of 4 volts and an internal resistance of 1 ohm. The motor coils have, also, a resistance of about 1 ohm each. The potential, therefore, outside the battery constantly varies, by the make-and-break, between 2 and 4 volts. This variation would disturb the regularity of the vibrations.

CARE OF RECORDER SIPHONS, INK, ETC.

Recorder siphons.—The punk furnished with tool boxes makes the best material for bending siphons. A lighted paper spill made of recorder tape is also a handy means of bending siphon tubes. A small spirit lamp is better. Tilt the lamp forward; the tubes must not be thrust into flame; a slight contact with the blue flame underneath will bend the tubes without melting and closing the tube. By using a spirit lamp both hands are available.

The best way of breaking off the surplus tube is by pressing it between the thumb nail and the forefinger. This usually leaves a clean, level break, requiring a very little grinding. A medium fine carborundum stone or a fine emery stick may be used to smooth the siphon point. Another method is by means of the miniature battery motor fitted with a small emery wheel.

Recorder ink is made by dissolving some of the more soluble aniline dyes in water, to which is added alcohol. In general, about one-fifth alcohol is correct, but the amount of alcohol depends upon the quality of the tape and dryness of the air. "Soluble-blue" aniline is good, and some of the "Diamond dyes" make good ink. It is best to use boiled water. After the aniline is thoroughly dissolved the ink should be run through a filtering paper. The bottle should be kept corked and care taken to exclude dust and lint from the ink well.

If siphon gets choked, heat the wax soldering strip used for putting siphons on and gently rub along siphon. This will force the ink out and remove the obstruction.

When recorders are not in use for some time the siphons should be immersed in water instead of ink. Empty ink well, fill with water, letting paper tape run till all ink is drawn out. Better still is the use of alcohol instead of water. When ink is drawn out of siphons, the alcohol filling tube, the alcohol can be returned to bottle and siphon left dry. On starting recorder again the ink will flow freely without assistance; the alcohol having evaporated leaves tube dry.

Ground connections.—In no case should the recorders be connected with the same ground as land lines or even to the same cable sheath that connect to instruments where Morse is used. Owing to the great delicacy of the recorder, this will cause the Morse working to disturb the recorder signals. (See remarks pertaining to ground connections appearing later in this chapter.)

AUXILIARY APPARATUS FOR SIPHON RECORDER WORKING.

Double keys are used similar to those shown in figure 11–15. The battery binding posts are on the sides, while the earth and line posts are at the back. Connections and switch used are shown in figure 11–15.

The signaling condensers may be either in the transmitting circuit, in the receiving circuit, or both. In the Alaskan cable offices the condenser is inserted in the receiving circuit only as shown in figures 11–15, 11–16, and 11–17. These condensers should be very solidly made and having ample thickness of dielectric to prevent short-circuiting by puncturing or rough handling.

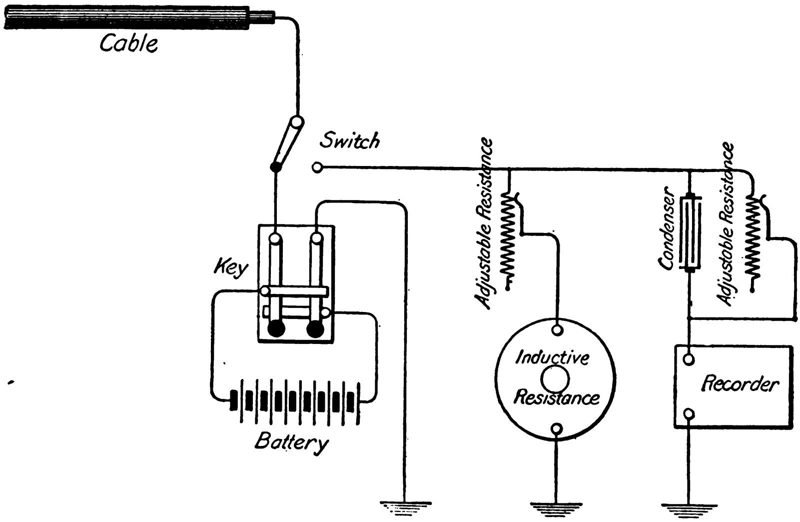


FIG. 11–15.—LONG SUBMARINE CABLES, SIPHON RECORDER SET, SIMPLIFIED CONNECTIONS.

At the offices on the longer cables is provided a large coil forming an inductance shunt to the cable. (Figs. 11–16 and 11–17.) This coil has resistance in series with it mounted in the same case with the condenser shunt.

The battery required to operate long cables with siphon recorder is small when compared with the operation of land lines. For example, the Seattle-Sitka câble, 1,085 miles, is operated with 10 ordinary dry cells; the Valdez-Sitka cable, approximately 600 miles, with 2 dry cells; the Juneau-Sitka cable, approximately 300 miles, with 1 dry cell. During extreme low insulation the Seattle-Sitka cable has been operated when less than one-tenth of one miliampere came through from the distant end. The traffic on the Seattle-Sitka cable is practically continuous for 15 or more hours each day, and it has been found that dry cells are entirely satisfactory. The dry cells for this service last from six to eight months. The condition of these cells should be frequently ascertained.

ARRANGEMENT OF INSTRUMENTS FOR OPERATING LONG CABLES.

As siphon recorders are now almost universally used on long cables, office sets of this kind only will be described. The simplest arrangement of the siphon recorder set is shown in figure 11–15. With the switch in sending position it is seen that the negative end of battery is put to line when the left key lever (dot) is depressed, and the positive when the right (dash) is depressed.

With switch set at receiving, the incoming currents pass through condenser and recorder to earth. On the longer cables Muirhead's arrangement of the circuit is shown in figure 11–16.

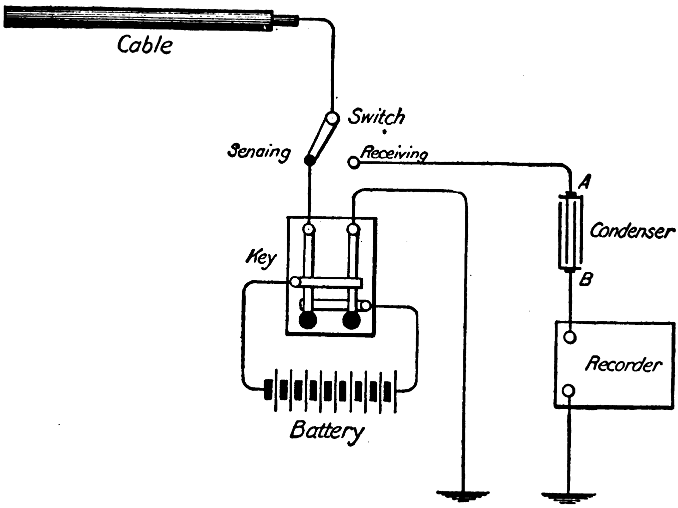


Fig. 11–16.—LONG SUBMARINE CABLES, SIPHON RECORDER, MUIRHEAD'S ARRANGEMENT OF CIRCUIT.

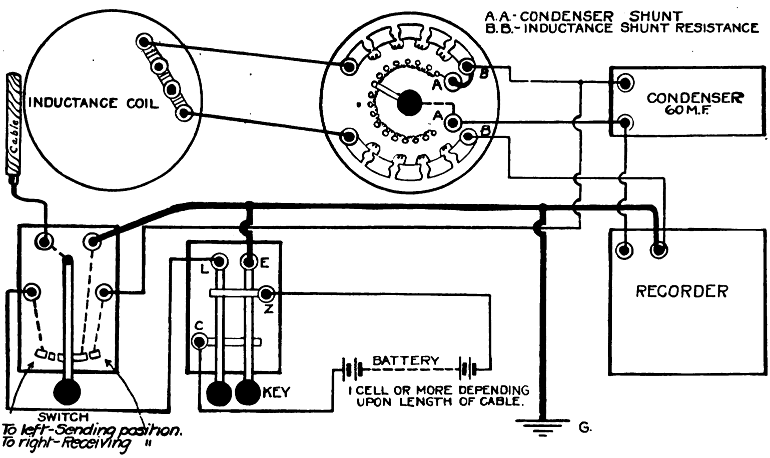


Fig. 11–17.—LONG SUBMARINE CABLES, ACTUAL CONNECTIONS AT ALASKAN CABLE OFFICES.

In the receiving circuit the incoming currents are first partly shunted to earth through the adjustable resistance and inductive resistance coil. This, while reducing the signals somewhat in amplitude, tends to make them squarer and more sharply defined. The unshunted portion of currents then pass on, part of them going directly to recorder and earth through the condenser shunt adjustable resistance, and the other through the condenser and recorder. By adjusting the resistances and condenser the signals can be leveled off to the most legible shape.

The actual circuit arrangement just described is shown in figure 11–17.

The inductance coil shown in diagrams is not used on short cables like Valdez-Seward-Cordova cables, about 264 statute miles.

Figure 11–18 is a diagram of circuits of a duplex and simplex system.

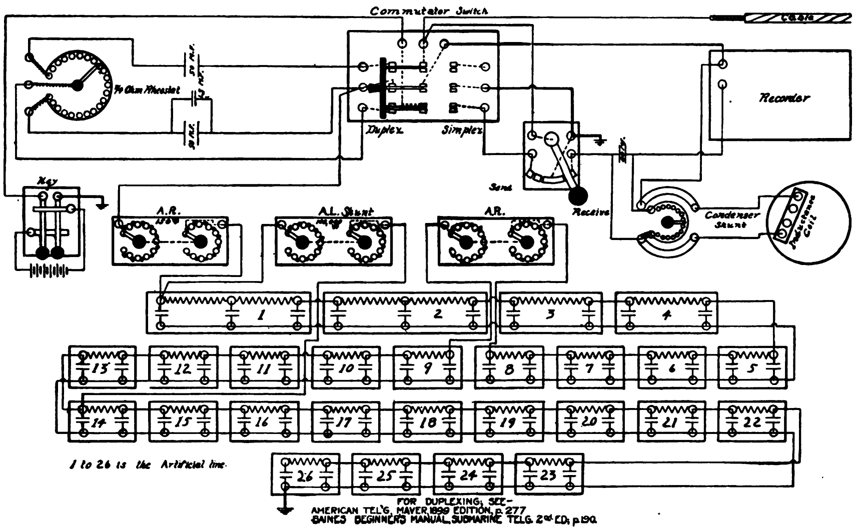


Fig. 11–18.—LONG SUBMARINE CABLES, SIPHON RECORDER, DUPLEX AND SIMPLEX SYSTEMS, CONNECTIONS.

AUTOMATIC TRANSMITTERS.

Where the traffic is heavy enough to warrant the expense of installation the automatic transmitter should be used. The maximum signaling speed of the cable may thus be maintained; the signals are uniform, and, in the words of a superintendent of a commercial cable company, "it does not stop to talk." The Cuttriss automatic transmitter, hereafter described, has proved very satisfactory on the Seattle-Sitka cable.

The apparatus uses a perforated tape automatically fed through the instrument by means of a small electric motor. The perforations are previously made on a machine similar to a typewriter and by means of them the dot-and-dash characters are transferred electrically to the cable conductor.

THE CUTTRISS AUTOMATIC TRANSMITTER.

The wiring of the Cuttriss automatic transmitter, figure 11–19, illustrates the method of operation of the instrument. It is the practice to connect, as auxiliary, transmitters of the ordinary telegraph type with the Cuttriss transmitter. The drive of the Cuttriss transmitter is a motor with permanent field magnets. The speed is governed by a make-and-break contact, which is adjusted by a knurled screw protruding through the end of the instrument case. The more continuous the "make," or, in other words, the closer the adjustment of governor contacts, the faster should be the speed. Each revolution of the armature shaft of motor turns the star wheel one-tenth of an inch. The outside star wheel contains two sets of holes into which the pins of the pickers fall when opposite the holes in the tape. The outside holes control the "dash" impulses. Inside the case is a master contact at which the make and break of the local circuits are made. The adjustment should

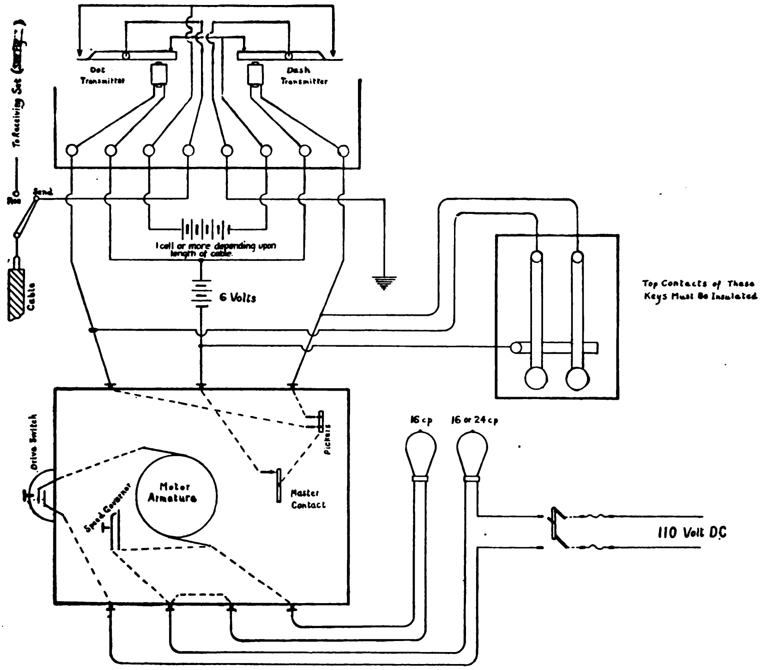


Fig. 11–19.—LONG SUBMARINE CABLES, CUTTRISS AUTOMATIC TRANSMITTERS, CONNECTIONS.

be such that the picker contacts are closed before the make is made on the master contact; also the picker contacts should be opened after the break of the master contact. Improper adjustment will be indicated by the pickers sparking. When sent out the instrument is carefully adjusted, but should later adjustment be necessary the following procedure is suggested:

See that the inside steel cam is fast on the shaft. Revolve the armature shaft until the slot in the steel cam is on top. At this point the pickers should drop exactly in the center of the holes of the outside star wheel. The pins of the two star wheels should always be exactly opposite each other. With the slot of the steel cam upward, it should be possible to revolve the armature shaft a portion of a turn without moving the star-wheel shaft. The screw on the master contact arm should then be adjusted for maximum period of contact per revolution. As the armature shaft is revolved the master contact should be broken just before the star wheel begins to move. The pickers should have very small play, just enough to maintain the "open" in the circuit. The make and break of the master contact should be properly timed. This is adjusted when necessary by rotating the vulcanite eccentric cam on the armature shaft so that the high point comes at the proper part of the cycle.

TRANSMITTER-TAPE PERFORATORS.

The perforator manufactured by the Kleinschmidt Electric Co., New York, has the appearance of a typewriter; the depression of any one key makes all perforation necessary for the corresponding character. It is usually manufactured to operate on 110-volt direct current, but can be manufactured to operate on higher or lower voltages.

This perforator requires no special skill for its operation, and has the advantage of being about three times as rapid as the familiar Muirhead type. One extra set of punches and dies should be kept on hand. Specifications for maintaining, cleaning, and adjusting the Kleinschmidt perforator may be obtained from the manufacturer.

NOTES ON THE EFFICIENT WORKING OF A CABLE STATION AND ON TROUBLES THAT OCCUR.

See that the batteries are kept in good condition and well insulated from each other and outside damp or metallic surfaces.

All office leads should be well insulated. It is better not to bunch them together or bend sharply at an angle. Whenever binding posts or switches are used they should be frequently overhauled and cleaned. A high resistance at a connection is a very common source of trouble.

Light, snappy sending over a long cable will produce weak and distorted signals at the distant end. All contacts should be uniformly made and with a cushiony or springy style. See that the levers of key spring back well against the back contact, which becomes a part of the line circuit when the opposite key is used. This contact also permits the cable to discharge to earth.

The amount of sending and receiving condensers to be used can best be regulated by experiment, the resistance and capacity of the cable and the amount of battery used being the chief basis to judge by (from 20 to 60 microfarads gives a range sufficient for all general conditions). Where no sending condensers are used it is well to interpose an inductance coil between the line and ground parallel with the receiving condenser and recorder. This inductance coil is to have a resistance in series with it for adjustment. The condenser is to be shunted by an adjustable resistance. With this inductance leak in circuit it will be necessary to increase the sending battery, as it acts as a shunt on the recorder. With a proper adjustment of the resistance in series with the inductance coil and of the resistance shunting the condenser, the signals can be made of uniform deflection and will lose that irregular rising and falling off which is a bad feature in long cables.

If the distant station complains of signals being small or weak it is well to test the battery for voltage at the cable terminals, and if the voltage shows normal the trouble is due to a high resistance caused either by bad contact of the key or other bad connections in the circuit. If there is a spare set in the office, switch over and ask if signals are any better. If the reply is negative the trouble must be in some connections which are common to both sets, which can be seen in the office diagram of connections. This is on the assumption that there is no trouble at the other station. If the distant station complains of key failing and states he gets no "dots" or only occasional "dots" from you the trouble will invariably be found in a dirty point either at the *front* contact of the "dot key" or the *back* contact of the "dash key." If the complaint is of "dashes" failing the positions are reversed—that is, at the *front* contact of the "dash key" and the *back* contact of the "dot key." A light touch with a very fine file will clean the key contacts. The receiving station should overhaul and clean his connections in the switch and see that his condenser and shunt connections and contacts are all right. A jumper or bridge of a small piece of wire can be put across the different connections in the switch to prove that the contacts are all right. A variable resistance in the inductance coil circuit, or condenser shunt circuit, or a faulty condenser will produce variable signals. After seeing that the connections are properly made and contacts clean, and the signals still vary from large round signals to small sharp signals and at times come normal, the condenser should be tested for insulation.

A faulty condenser will give the above effect. In case communication is lost with distant station, cut out switch and office connections and run wires to line and earth direct where they enter office and connect up as in diagram (fig. 11–15). After calling for a sufficient time and no answer received, short-circuit condenser by putting a wire across from plate "A" to plate "B" and call again. This will prove if trouble is local or otherwise.

After both stations have overhauled their office connections and the trouble still remains, tests should be made of the main cable and earth cable. In the case of long underground cables it very often happens that joints become corroded and eaten away. This is particularly the case where there are electric railways in the vicinity.

By keeping the field magnets adjusted close to the signal coil the trouble from small, quick extraneous currents will be very much lessened. If the earth currents are very strong the shunt on the receiving condenser should be greatly increased or set to infinity. When the earth currents interfere with operation and the insulation of the cable will permit, the sending batteries may be increased.

The signals can be regulated by the recorder shunt to the required size. One of the principal things in maintaining good signals is the syphon and its vibration. The point of the syphon should be uniformly ground and bent so as the best flow of ink is obtainable. If the nose is bent too abruptly or not far enough a very poor line is the result. It will be found when a new syphon is put on that perhaps the period of vibration is different from what it was for the old syphon. It will then be necessary to adjust the interrupter by turning back and forth and sliding the weight on the armature lever up and down until the proper period is obtained. Also, the rheostat in the battery circuit can be changed to give desired effect. If the syphon is not properly mounted it will be difficult to get proper vibration. If blots of ink form rapidly on the nose of the syphon it is better to change it and substitute one better ground. By heating a small iron and putting a little wax on the nose of syphon a rough line can be improved. Once the kind of syphon that gives best results is established a dozen or so similar ones properly ground should be made ready for use so the one can be readily mounted when necessary. Keep the bearings of the motor well oiled and the battery contact maker cleaned and free from sparking. If the contacts are too close and an arc forms, the battery will be run down quickly and motor run irregularly.

GROUNDS FOR SUBMARINE CABLES IN OR NEAR LARGE CITIES.

The earth in large cities and vicinity is charged with positive electricity from electric-car lines and leakage from electric-light circuits. This positively charged earth causes currents to flow into the surrounding country and especially on any conductor leading away from the cities, such as the armor of a submarine cable which lands in the cities.

The delicate current used in submarine telegraphy is much disturbed by these varying earth currents when the ground is made to the earth or cable armor in or near the large cities. For this purpose an extra cable is run some distance into the sea, its length depending on the amount of the disturbance caused by the above-mentioned earth charge.

The single copper conductor of this earth cable should not be grounded directly to the armor or other metallic body at the extremity of the earth cable, for local galvanic action will occur between the two dissimilar metals, and trouble from this cause will ensue. The copper core of the single-conductor ground cable should be spliced to an iron wire, and all of the copper core and the joint carefully insulated, to entirely exclude moisture, and this iron wire carefully soldered to a mass of iron and then sunk in the bottom of the sea.

A better method is to use a two-conductor cable from cable landing to several miles out to sea, splicing one conductor of the two-conductor cable to the conductor of the long single-conductor cable and grounding the other conductor in the following manner:

To connect the second conductor of the twin core to the sheathing wires of the cable, proceed by preparing the armor wires for an overlapping splice in the usual manner for joining two single-core cables, except that on the end that usually has all the wires cut off at the splice (the single-conductor cable in this instance) five or six of the armor wires are made 7 or 8 inches longer than the rest, so as to provide a convenient surface for making the ground connection. On the other cable end (two-conductor cable) the armor wires will, of course, be left 20 or 30 feet long. The regular cable conductor is then spliced in the same manner as when joining single-conductor cables together. After this joint is completed and served with tape or spun yarn, mill (wrap) the copper strands of the extra or ground conductor around the five or six armor wires that were left longer for that purpose, making a joint 4 or 5 inches in length, which, if possible, should be carefully wiped with solder. Both the copper and iron wires should be thoroughly cleaned before the joint is made, and these joints thoroughly insulated with pure rubber or Kerite tape, applied warm. It is highly important that moisture does not come in contact with the joints between the copper and galvanized-steel armor wires. After serving this joint and the core splice with tape or spun yarn as a bed for the armor wires, you have a condition that does not differ greatly from the joint of a two-conductor cable, the splice being completed with the long ends of armor wires and served in the ordinary manner.

In these methods there are no dissimilar metals exposed to the water to cause trouble.

By soldering the grounds to the armor at the end of the two-conductor cable the continuation of the armor to the distant end of the cable makes one of the best grounds.

This method is employed by the Commercial Cable Co. at New York City. The two-conductor cable extends 10 miles to sea from the beach on which the commercial cable lands near New York. The copper core to the ground connection is joined to six different iron wires to insure a good ground connection, each joint and all copper carefully insulated, and each of the six iron wires wrapped around the armor and soldered.

CABLE TESTING.

The remarks appearing in this manual concerning the general necessity for testing cable regularly, apply with added force in the case of long submarine cables.

By applying regular tests incipient faults will frequently disclose themselves long before they become sufficiently serious to interfere with the working, giving ample time to notify the repair ship, if the faults are out at sea. Furthermore, it is absolutely necessary in case of cables to locate them accurately by tests, though this part in its refinements belongs in general to the cable-ship experts. The subject of cable testing is extensively entered into by Kempe in his Handbook of Electrical Testing.

The works already cited by Wilkinson and Bright also describe various methods. Students' Guide to Submarine Cable Testing (Fisher & Darby), Electrical Testing for Telegraph Engineers (J. Elton Young), Beginners' Manual of Submarine Cable Testing and Working (G. M. Baines), and Testing of Insulated Wires and Cables (Webb) are recommended treatises on testing. The Students' Guide and the three latter are compact treatises which are quite elementary and easily understood.

It is proposed to describe such tests as are usually desirable at cable stations.

In making tests using delicate testing instruments such as the galvanometer, let the rule be to begin with large fraction of shunt and small value of battery, gradually decreasing fraction of shunt and increasing battery. This will prevent damage to instruments due to excessive current strength.

In making the approximate measurements at stations the Weston milliammeter and voltmeter set may be used. These, of course, will not give sufficiently accurate results when high-resistance faults exist. The Wheatstone bridge may be used whenever measuring the ordinary resistances, and the ohmmeter will answer for approximations. The Fisher cable-testing set, described later in this chapter, combining, as it does, so many necessary instruments is convenient for Morse stations.

The reflecting galvanometer is a necessity in accurate cable measurements. Not only does it give better results than any other form with Wheatstone bridge measurements, but it is a necessity in insulation resistance and capacity measurements, both of which are very important in cable work. Before considering them the reflecting or mirror galvanometer will be described.

REFLECTING GALVANOMETERS.

Any pointer or indicator attached to the movable coil or needle of the galvanometer increases the mass to be moved and decreases the sensitiveness. A delicate mirror being attached to the coil or needle may be used to reflect a beam of light onto a scale, thus giving a weightless pointer or indicator as long as may be desired and consequently great sensitiveness. Another way of utilizing the reflecting principle is to view the reflected image of the scale with a small telescope, noting the number on the scale intersected by a vertical thread in the telescope. Formerly the Thomson reflecting galvanometer (fig. 11–20) was exclusively used for any case requiring great sensitiveness.

The beam of light from the lamp L shining through the slit in the shield is reflected from the mirror attached to the suspended magnetic needle N and projected on some point of the scale S.

The needle swings in a small space in the middle of the coils, and the direction and strength of the controlling force is given by the bar magnet *M*. By this arrangement it is seen that a very small movement of the needle and the attached mirror will be greatly magnified in the movement of the spot of light on the scale.

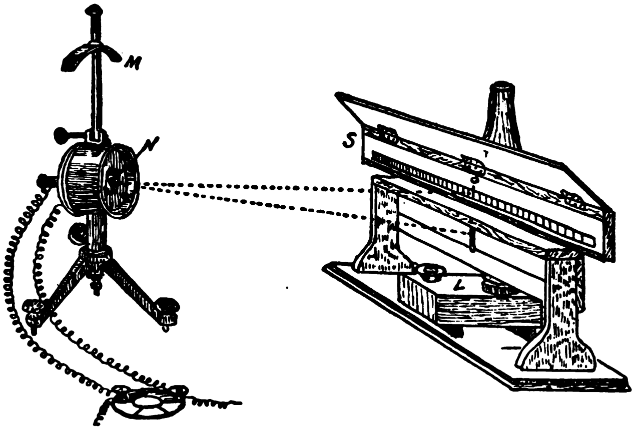


Fig. 11–20.—LONG SUBMARINE CABLES, TESTING, THOMPSON REFLECTING GALVANOMETER.

The Thomson galvanometer is well adapted to laboratory work, but, for testing cables after they are laid, where there are always some disturbing currents, it has been found that the Sullivan Universal galvanometer gives better results; it is not so sensitive as the Thomson but is more "dead beat" and manageable. The coil is suspended in the field of a permanent magnet and is dampened with a fine brush.

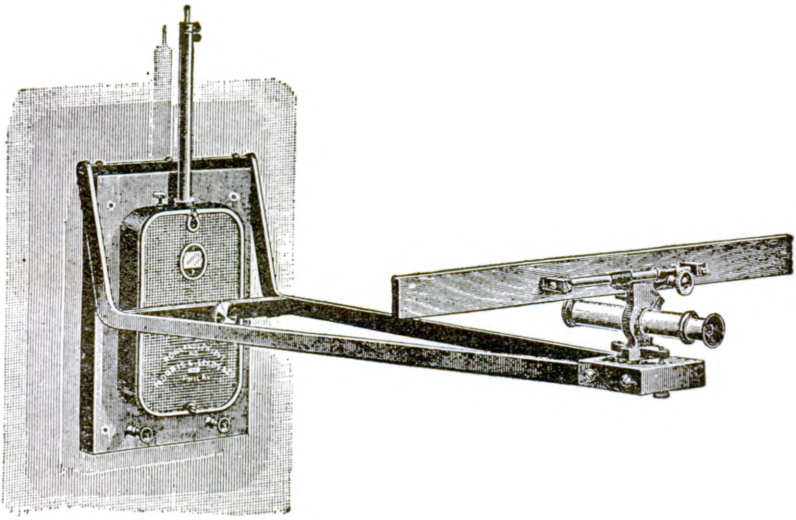


Fig. 11–21.—LONG SUBMARINE CABLES, TESTING, D'ARSONVAL REFLECTING GALVANOMETER.

Galvanometers of the D'Arsonval class, with a suspended coil turning in the field of a permanent magnet, are in general use for all kinds of measurements. While usually not of such a high degree of sensitiveness as the Thomson, they are much more "dead beat" and manageable. These are quite generally used as mirror galvanometers.

An excellent form for cable-station use is shown in figure 11–21. As will be noted, these use the small telescope to view the scale and should be so mounted that the light from the window or lamp will fall on the scale.

It will also be noted that this instrument is practically a duplicate of the one described in chapter 4 of this manual, except that it is designed for mounting permanently or semipermanently on a wall while the one described in chapter 4 is equipped with a tripod in order that the instrument can be conveniently set up in the field.

SHUNTS.

As explained in chapter 4 of this manual, any delicate galvanometers like the above can not be used in most cases with the whole current involved in the measurement, as even through a very great resistance a single cell will cause the reflected image to move completely off the scale. Consequently shunts are provided which allow certain definite portions of the current (usually $\frac{9}{10}$, $\frac{99}{100}$, or $\frac{999}{1000}$) to pass through the shunt, and $\frac{1}{10}$, $\frac{1}{100}$, and $\frac{1}{1000}$, respectively, to go through the galvanometer.

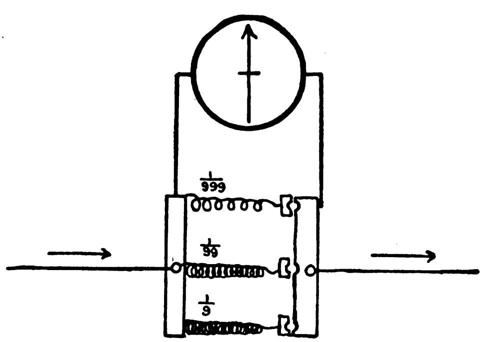


Fig. 11–22.—LONG SUBMARINE CABLES, TESTING, SHUNT, SIMPLIFIED DIAGRAM.

The simplified diagram is shown in figure 11–22.

By placing the plug at one or the other of the points a divided circuit is formed, and a certain part of the current will flow through the shunt and the other through the galvanometer. For example, $\frac{1}{99}$ has $\frac{1}{99}$ as much resistance as the galvanometer. So $\frac{99}{100}$ of the current will flow through this and $\frac{1}{100}$ through the galvanometer. Hence, the deflection with this shunt will be only $\frac{1}{100}$ as much as it would be if no plug were put in the shunt to bring the deflection within readable limits.

Remarks on the shunt.

Resistance of shunt compared to resistance of galvanometer.	Current through— Shunt.		Current through— Galvanometer.		Whole current.	Multiplying power of shunt.
$\frac{1}{999}$	$\frac{999}{1000}$	+	$\frac{1}{1000}$	=	1	1,000
$\frac{1}{99}$	$\frac{99}{100}$	+	$\frac{1}{100}$	=	1	100
$\frac{1}{9}$	$\frac{9}{10}$	+	$\frac{1}{10}$	=	1	10
No shunt	0	+	1	=	1	1

Multiply the deflection of the galvanometer by the multiplying power of the shunt to obtain what the true deflection would be with no shunt, when all current passes through the galvanometer.

Let G=Resistance of galvanometer,
S=Resistance of shunt,
M=Multiplying power of shunt,

Then $M=\frac{G+S}{S}$

$SM=G+S$

$G=SM-S=S(M-1)$

$S=\frac{G}{M-1}$

Example: Let $S=1$ and $G=99$

Then $M=\frac{99+1}{1}=100$

$G=1\times(100-1)=99$

$S=\frac{99}{100-1}=1$

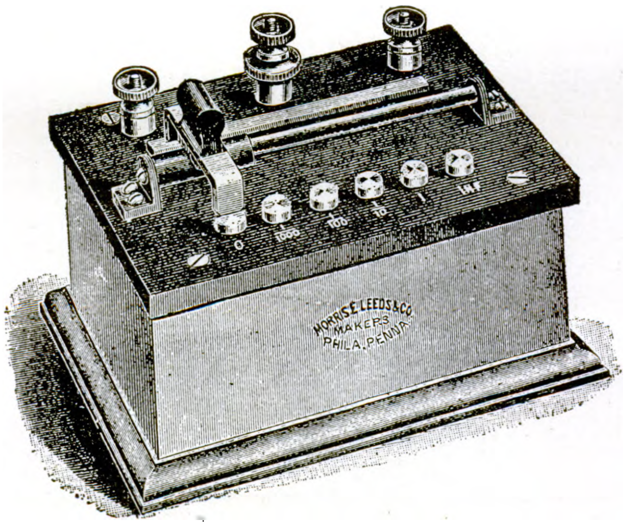


Fig. 11–23.—LONG SUBMARINE CABLES, TESTING, AYRTON UNIVERSAL SHUNT.

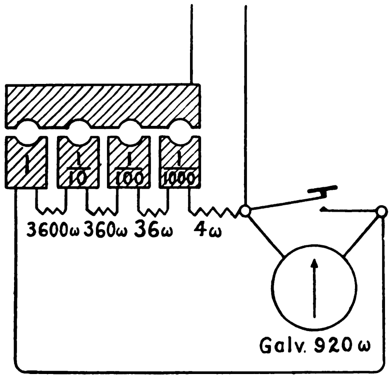


Fig. 11–24.—LONG SUBMARINE CABLES, TESTING, AYRTON SHUNT, CONNECTIONS

The Ayrton universal shunt (figs. 11–23 and 11–24) is now frequently used with galvanometers of moderate resistances. One of these can be used with any galvanometer regardless of their relative resistances, and it has the advantage of being accurate for condenser and capacity measurements as well. In this the shunts are more conveniently marked $\frac{1}{1000}$, $\frac{1}{100}$, $\frac{1}{10}$, $\frac{1}{1}$.

The principle of the Ayrton universal shunt is that where the resistance of the galvanometer is small in comparison with the total resistance of the shunt the resistance of the galvanometer is ignored.

M=Multiplying power of shunt.
G=Resistance of the galvanometer.
S=Resistance of the shunt.

$$M=\frac{G+S}{S}$$

Consider that resistance of the galvanometer itself is zero and that the plug is in the $\frac{1}{1000}$ shunt, where the multiplying power is 1,000, then:

$$1000=\frac{G+S}{S}$$

Call that part of the shunt in series with the galvanometer, the resistance of the galvanometer, or 3,600+360+36=3,996 ohms, and the resistance of the actual shunt X.

Then $1000=\frac{3996+X}{X}$ or $1000\,X=3996+X$ or $999\,X=3996$, where X or the shunt equals 4 ohms.

Substituting 4 ohms for S and 3996 for G:

Plug in $\frac{1}{1000}$, then $M=\frac{3996+4}{4}$ or $\frac{4000}{4}$ or $M=1{,}000$

Plug in $\frac{1}{100}$, then $M=\frac{3960+40}{40}$ or $\frac{4000}{40}$ or $M=100$

Plug in $\frac{1}{10}$, then $M=\frac{3600+400}{400}$ or $\frac{4000}{400}$ or $M=10$

Plug in 1, then $M=\frac{0+4000}{4000}$ or $\frac{4000}{4000}$ or $M=1$

The multiplying power is proved in each case, and it can also be seen that the following rule in the Sullivan marine galvanometer shunt is proved, i. e.—

To obtain the multiplying power of the shunt, divide the total resistance in the shunt by the amount of the shunt cut in.

As an actual fact, though, the galvanometer in the Fisher's set at Seattle has 920 ohms resistance, adding that also to the G resistance used in the examples above, the following results are obtained, showing that even 920 ohms in the galvanometer itself can be ignored, and the Sullivan rule is again proved:

Plug in $\frac{1}{1000}$, then $M=\frac{3996+920+4}{4}$ or $\frac{4920}{4}$ or $M=1230$

Plug in $\frac{1}{100}$, then $M=\frac{3960+920+40}{40}$ or $\frac{4920}{40}$ or $M=123$

Plug in $\frac{1}{10}$, then $M=\frac{3600+920+400}{400}$ or $\frac{4920}{400}$ or $M=12.3$

Plug in 1, then $M=\frac{0+920+4000}{4000}$ or $\frac{4920}{4000}$ or $M=1.23$

From the last set of examples, where the galvanometer has an actual resistance, nearly one-fourth that of the shunt, it is found that though M is 1, it should really be 1.23; yet the multiplying power of 10, 100, and 1000 is exact, considering the M for 1 as the unit whatever it may be. Therefore, the relation is the same as in the first set of values, where the galvanometer itself had no resistance.

For—

1 times 1.23=1.23
10 times 1.23=12.3
100 times 1.23=123
1000 times 1.23=1230

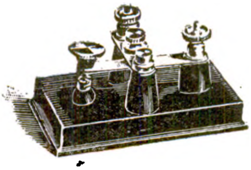
and the multiplying power is unchanged by counting or not counting the resistance of the galvanometer.

Another form of Ayrton shunt is shown in chapter 4 and is specially adapted for portable testing sets. With the latter type the circuit key is made a part of the apparatus. It will be noted that with these shunts the fractional divisions are 1, 0.1, 0.01, 0.001, 0.0001. The latter fractional division is a convenient addition when observing galvanometer constant, using one-tenth megohm as known resistance, as by its use the full voltage of testing battery can be used with De Arsonval galvanometers having a sensibility approximate to those usually furnished.

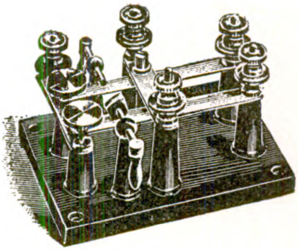
The method of making measurements of insulation, capacity, and ohmic resistance, using instruments furnished with the Signal Corps electrical-instrument case, are fully described in chapter 4 of this manual. Inasmuch as tests on long submarine cables using the same type instruments would be similarly made, a repetition of the description would be superfluous. However, with long submarine cables great care must be exercised to avoid doing anything that will impair the insulation. The voltage used in making tests must be kept as low as is possible to attain desired results. Readings should be taken with positive pole of battery to ground and then with negative pole to ground. Should there be a variation in these readings, the mean of the two should be accepted as true reading.

When the cable exceeds 100 miles in length, capacity measurements should be made by Thomson's or Gott's methods. Descriptions of these are found in the books of references.

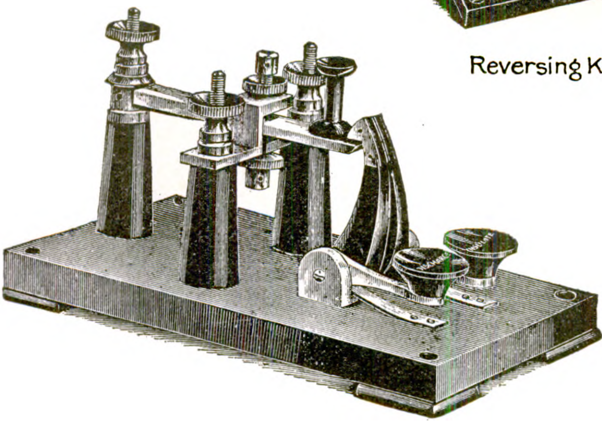
Figure 11–25 shows some of the special instruments used in submarine-cable testing at cable offices of the Washington-Alaska Military, Cable and Telegraph System.



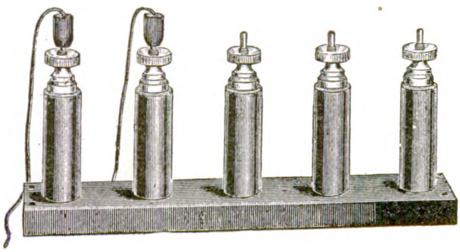
Short-circuiting Key



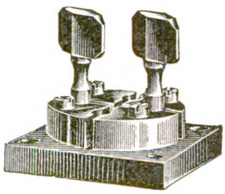
Reversing Key



Discharge Key for measuring capacity



High-insulation Binding Posts



Double Plug Switch

Fig. 11-25.—LONG SUBMARINE CABLES, TESTING, SPECIAL INSTRUMENTS USED.

If the piece of cable to be measured is short, its insulation resistance will probably be very high, and a battery of from 50 to 100 cells in series will be required. These may be the smallest-size dry cells, or one of the regular boxes of testing batteries. The regular testing battery is composed of chloride of silver cells. On account of their first cost and liability to be ruined by even a brief short circuiting, it is advisable to reserve this type of battery for insulation measurements only.

CONDUCTOR RESISTANCE.

This is usually called "copper resistance" (C. R.) in books on cable testing. To measure the resistance of sound cable when it is coiled in the tanks, when both ends are available the methods before given and cited in reference books may be followed. Of course, the most satisfactory and accurate method is with some form of Wheatstone bridge and mirror galvanometer when these instruments may be had. Good approximations may be made with the ohmmeter, or the combination of voltmeter and milliammeter, as stated in land-line testing. It is evident that if we know the resistance of the cable per mile, and find the total resistance of the cable, the length of it is equal to the total resistance divided by the resistance per mile. This method is called to attention because of its constant use in determining the lengths of pieces of single conductor cable. Of course, the temperature must be taken into account, and the resistance measured must be reduced to that at the temperature at which the resistance per mile is stated. A table of temperature coefficients is given below.

Temperature coefficients for copper resistance.

Difference in degrees—		Coefficient.	Difference in degrees—		Coefficient.
Fahrenheit.	Centigrade.		Fahrenheit.	Centigrade.	
1	0.5	1.002	16	8.9	1.034
2	1.1	1.004	17	9.4	1.036
3	1.7	1.006	18	10	1.0385
4	2.2	1.008	19	10.5	1.041
5	2.8	1.010	20	11.1	1.043
6	3.3	1.013	21	11.6	1.045
7	3.9	1.015	22	12.2	1.047
8	4.4	1.017	23	12.7	1.049
9	5	1.019	24	13.3	1.051
10	5.5	1.021	25	13.8	1.054
11	6.1	1.023	26	14.4	1.056
12	6.6	1.025	27	15	1.058
13	7.2	1.0275	28	15.5	1.060
14	7.7	1.030	29	16	1.062
15	8.3	1.032	30	16.6	1.065

In using this table note that in passing from a higher to a lower temperature divide the observed resistance by the number opposite the degrees of difference of temperature, and in passing from lower to higher multiply the same.

Example: A piece of cable is measured at 85° F. and has a resistance of 100 ohms. The resistance per mile (9.5 ohms) is given at 75° F. The difference is 10° F. higher than the standard.

$$100 \div 1.021 = 97.94 \text{ ohms at } 75° \text{ F.}$$

and the length of the piece is $97.94 \div 9.5 = 10.31$ miles.

While the length of single-conductor cable can be ascertained accurately by this method, it has been the author's experience that with multiple-conductor twisted-pair cable only an approximation of the length can be obtained, because on account of the twists and lay the conductors are actually longer than cable. Not only are pairs twisted together, but the pairs are wound spirally around the longitudinal center.

After laying the cable, in attempting to measure its resistance through the ground connections at each end the simplicity vanishes of measuring with the Wheatstone bridge and balancing until the galvanometer is at zero. It will be found that after making connections and before depressing the battery key that if we depress the short-circuit key a deflection will generally be noted. This is largely due to earth current (called E. C. in reference books). If it were steady it could easily be dealt with. Unfortunately, it is not, and it is constantly varying in direction as well.

Two ways of measuring to eliminate earth-current effects are described in works on cable testing called, respectively, "Quick reversals" and "False zero." (See pp. 59–62, 3d ed., Students' Guide to Submarine Cable Testing, Fisher & Darby.) A brief additional description of these may be useful.

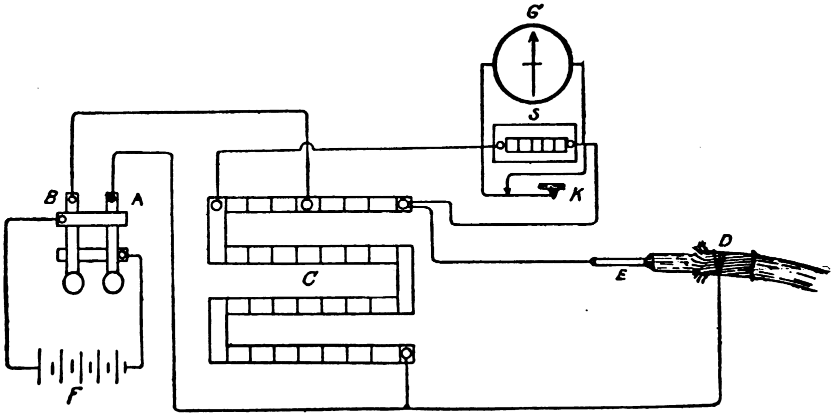


Fig. 11–26.—LONG SUBMARINE CABLES, TESTING, COPPER RESISTANCE, CONNECTIONS.

Connections for measuring copper resistance are shown in figure 11–26. *A B* is the reversing key, *C* is the Wheatstone bridge, *G* is the galvanometer, *S* the universal shunt, *K* the short-circuit key, *F* the testing battery. The bridge is connected with the cable conductor *E*, prepared as shown, and *A* and the bridge are connected to a brightened place on the cable armor wires for ground connections, as explained under "Capacity measurements." Of course in this case the distant end of conductor is connected with the armor wires or ground. As will be seen, by depressing *B* the copper (or carbon) end of the battery will remain connected with the ground, while the zinc goes to cable conductor through the bridge. Due to the fact that the "zinc current," as it is called, tends to clear away corrosion when measuring to locate a fault, measurements made with it usually show lower resistances than when carbon or copper is put to line by depressing *A*. However, as little effect of this kind will be noted in sound cable with distant end well connected with ground as stated, we shall assume disturbances due only to earth currents in measuring.

The method by quick reversals will first be described. Depress *B*, wait a second or two, and depress *K*. Balance as rapidly as possible, noting resistance. Release *B*, then depress *A* and *K*, and again balance quickly. The mean of these resistances will give the one approximately correct, unless there is too great a difference between them, in which case the correction on page 56, 3d ed., Fisher & Darby, should be applied.

Balancing to false zero (F. Z.) is the usual method of providing for earth currents in measurements of conductor (copper) resistances of cable.

Before depressing *A* or *B*, if we depress the short-circuit key we shall generally note a deflection. This is due to the earth current. Suppose it to be fairly steady, its direction and amount should be noted. If variable, its mean in the time usually occupied by balancing should be noted. This is the false-zero position to which we balance, instead of the true or instrumental zero we have heretofore considered. If the earth current or false zero is constantly varying, it should be noted just before and just after taking a measurement, and the false-zero position taken as the mean. Several measurements should be made until several successive results are obtained which accord fairly well. A good measurement of the copper resistance of the sound cable is an absolutely necessary preliminary to the location of faults when they occur.

The usual form of Wheatstone bridge used at Alaskan cable stations is shown in figure 11–27.

The form of report below illustrates the manner of tabulating data pertaining to long submarine cables.

The data which follows illustrates the character of report turned in on completion of cable.

RECORD OF CABLE TESTS.

U. S. SIGNAL CORPS.

Date____________ Place___________________
Tests made by___________________
Submarine cable number—between_______________________and______________________

Galvanometer constant.

(Through 100,000 ohms.)

Kind of galvanometer__________________Voltage of battery___________________
Shunt__________________________________Deflection { Right____________ Left_____________ Mean_____________
Constant per volt____________

INSULATION.

Cable current: Deflection..........................(right or left), with shunt............................
Voltage of battery.................................. Shunt..................................

Deflections.	Zinc.	Carbon.	Mean.
1st min...............	....	....	....
2d min...............	....	....	....
3d min...............	....	....	....
4th min...............	....	....	....
5th min...............	....	....	....

Absolute insulation end of three minutes................

COPPER RESISTANCE.

Deflection.....................
Earth current.................with shunt.................
Voltage of battery................. Bridge ratios.................
Resistance, zinc to line.................
Resistance, carbon to line.................
Mean.................
The records show that the resistance should be — ohms.
Capacity measurements made when directed.

NOTE.—Connect galvanometer so that with zinc to line in insulation test the deflection will be to left.
One copy of this record will be retained and three mailed to the officer in charge.

DATA PERTAINING TO THE SITKA-SEATTLE CABLE WHEN IT WAS LAID.

(This data is shown as an example to be followed.)

Type.	Nautical miles.	C. R. 60°.	C. R. temperature at bottom.	Sitka-Seattle.	Seattle-Sitka.	Temperature at bottom.
		Ohms.	*Ohms.*	*Ohms.*	*Ohms.*	°*F.*
S. E. Sitka, 1903	1.987	16.92	16.38	16.38	7,590.26	45
Inter., 1903	6.533	55.66	53.89	70.27	7,573.88	45
Do	9.040	77.02	74.57	144.84	7,520.49	45
Do	11.672	99.44	96.28	241.12	7,445.42	45
Deep-sea, 1903	6.768	57.66	55.82	296.94	7,349.14	45
Do	7.800	66.45	64.33	361.27	7,293.32	45
Do	4.914	41.86	40.17	401.44	7,228.90	41
Do	43.365	369.46	354.60	756.04	7,188.80	41
Do	61.264	521.97	496.59	1,252.63	6,834.22	37
Do	40.179	342.33	325.68	1,578.31	6,337.60	37
Do	19.378	165.10	157.07	1,735.38	6,011.90	37
Do	59.298	505.22	480.65	2,216.03	5,854.88	37
Do	50.172	427.46	406.67	2,622.70	5,374.23	37
Do	5.050	43.03	40.93	2,663.63	4,967.56	37
Deep-sea, 1904	21.780	185.56	176.53	2,840.16	4,926.63	37
Deep-sea, 1903	63.370	539.91	513.66	3,353.82	4,750.10	37
Do	14.860	126.60	120.44	3,474.26	4,236.44	37
Do	6.770	57.68	54.87	3,529.13	4,116.00	37
Deep-sea, 1904	2.470	21.04	20.01	3,549.14	4,061.13	37
Deep-sea, 1903	54.470	464.08	441.51	3,990.65	4,041.12	37
Do	17.000	144.84	137.79	4,128.44	3,599.61	37
Do	91.170	776.77	739.00	4,867.44	3,461.82	37
Do	12.900	109.90	104.55	4,971.99	2,722.82	37
Do	13.060	111.27	105.86	5,077.85	2,618.27	37
Do	2.800	23.85	22.69	5,100.54	2,513.41	37
Do	17.440	148.59	141.36	5,241.90	2,489.72	37
Deep-sea, 1904	.968	8.25	7.85	5,249.75	2,348.36	37
Do	1.832	15.60	14.83	5,264.58	2,340.51	37
Do	20.650	175.94	167.38	5,431.96	2,325.68	37
Do	20.310	173.04	164.62	5,596.58	2,158.30	37
Do	22.200	189.14	181.53	5,778.11	1,993.68	41
Do	21.540	183.52	176.14	5,954.25	1,812.15	41
Do	8.910	75.91	73.50	6,027.75	1,636.01	45
Inter., 1903	3.718	31.67	30.66	6,058.41	1,562.51	45
Do	32.230	274.60	265.87	6,324.28	1,531.85	45
Do	14.702	125.26	121.28	6,445.56	1,265.98	45
Do	24.386	207.77	201.17	6,646.73	1,144.70	45
Inter., 1904	9.800	83.50	80.84	6,727.57	943.53	45
Do	11.020	93.89	90.91	6,818.48	862.69	45
Do	10.970	93.46	90.49	6,908.97	771.78	45
Do	10.950	93.29	90.32	6,999.29	681.29	45
Do	11.370	96.87	93.79	7,093.08	590.97	45
Inter., 1903	4.660	39.70	38.44	7,131.52	497.18	45
Inter., 1904	1.110	9.45	9.15	7,140.67	458.74	45
Inter., 1903	16.420	139.90	135.45	7,276.12	449.59	45
Do	5.760	49.07	47.51	7,323.63	314.14	45
Do	14.020	119.45	115.66	7,439.29	266.63	45
Deep-sea, 1904	8.000	68.16	66.00	7,505.29	150.97	45
Inter., 1903	7.700	65.60	63.52	7,568.81	84.97	45
S. E. Seattle, 1903	2.600	22.15	21.45	7,590.26	21.45	45
Total	931.336	7,934.96	7,590.26			
Earth, Seattle	4.477	40.43	39.26			
Total	935.813	7,975.39	7,629.52			

	Ohms.
C. R. from buoy to Sitka	7,496.000
C. R. from buoy to Seattle through office to dock	94.617
Total	7,590.617
C. R. of Seattle ground end	39.265
Total	7,629.882

Average D. R., absolute 2.25 megohms; 2,104 megohms per nautical mile.

Capacity "1903 type" .... 737.156 nautical miles, at 0.593=437 microfarads.
Capacity "1904 type" .... 183.880 nautical miles, at 0.472= 87 microfarads.
Seattle shore end to dock .... 6 microfarads.

Total capacity by Gott's method from Arlington Dock to Sitka, Alaska .... 530 microfarads.

Average temperature, Seattle to Sitka, 39.1° F.
Distance on charts, Seattle to Sitka, 856 nautical miles.

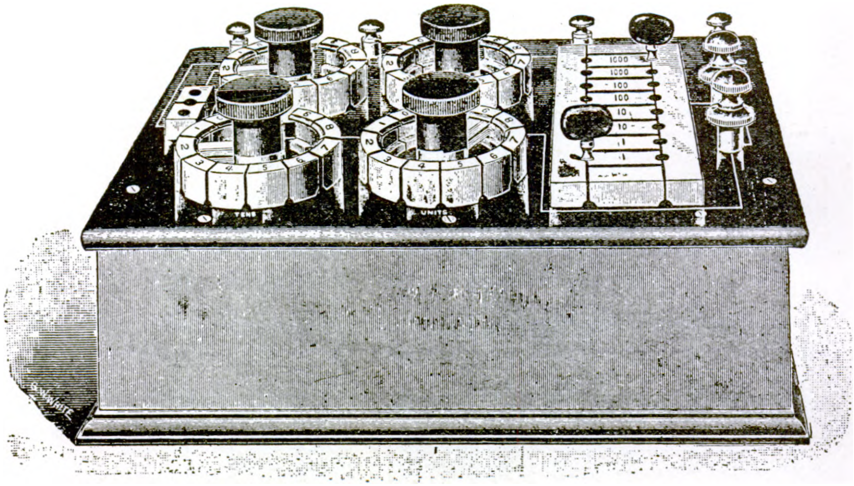


Fig. 11–27.—LONG SUBMARINE CABLES, TESTING, WHEATSTONE BRIDGE.

DESCRIPTION OF FISHER CABLE-TESTING SET NO. 2.

NOTE.—In all measurements, with this set, let the rule be to begin with large fractional value of shunt and small battery, gradually decreasing the shunt and increasing the battery.

This set shown in figure 11–28 was originally designed by Mr. H. W. Fisher. It is intended for work where a strictly portable set is required.

As it will frequently be used for locating trouble, a special arrangement of the bridge has been adopted so as to greatly facilitate Murray & Varley loop tests

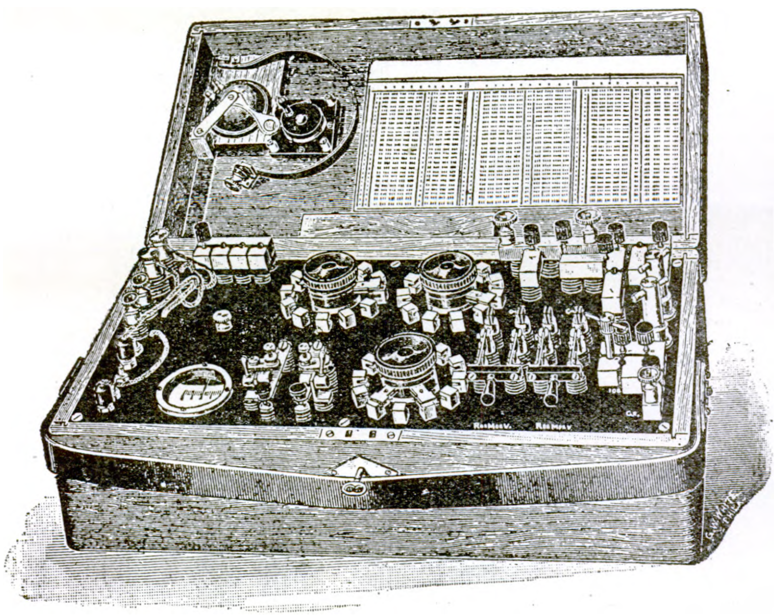


Fig. 11–28.—LONG SUBMARINE CABLES, TESTING, FISHER CABLE TESTING SET NO 2.

for faults. Mr. Fisher has also introduced a method new to portable cable testing sets for locating breaks in cables where the conductor has parted; and, in addition to the usual one, a new method for measuring capacity in which no galvanometer is required, a telephone being used in place of it.

The parts are mounted on corrugated hard-rubber pillars, which extend above and below the base.

This arrangement gives a very good insulation, and one that will be found entirely satisfactory, except under the most trying condition of moisture. The changes from one test to another are accomplished very easily and without the use of inconvenient flexible cords. They are effected by double-throw switches which are plainly marked so that it is not necessary to memorize a complicated scheme of connections.

The standard of capacity has a single value of $\frac{3}{10}$ microfarad.

The standard high resistance is 100,000 ohms, and is also a single value, not subdivided.

In the Wheatstone bridge a marked variation from the usual commercial type has been made. The change is introduced to facilitate measurements for the location of faults. It is an extension of the Kelvin-Varley slides, and, since

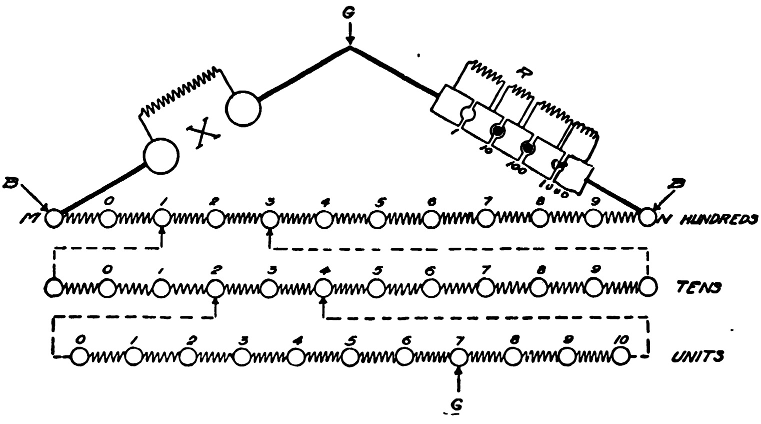


Fig. 11–29.—LONG SUBMARINE CABLES, TESTING, FISHER CABLE TESTING SET NO. 2. WHEATSTONE BRIDGE ARRANGEMENT.

it may not be generally known, the following description is given. It is a form of Wheatstone's bridge resembling those having a slide wire in which the values of the rheostat are fixed and the two arms of the bridge are varied until a balance is effected. The arrangement is represented in diagram in figure 11–29.

The points marked *G* and *B* are the points of attachment for the galvanometer and battery, respectively. At *R* are represented the four coils of the rheostat, any one of which may be used, and at *X* the unknown resistance. Between *M* and *N* are eleven coils of equal value, which form the bridge wire. There is a contact point between each coil and the one next to it. The other coils shown in the series marked "Tens" and "Units" are used to subdivide the coils of the bridge. They constitute what may be called an electrical vernier, by means of which the bridge wire is subdivided to thousandths of its total value. The two arrows in contact with the points marked 1 and 3 in the "Hundreds" row and with the 2 and 4 in the "Tens" row represent contact arms which can be moved along to make contact at any of the contact points, but are always at the same distance apart, so that they have two coils between them.

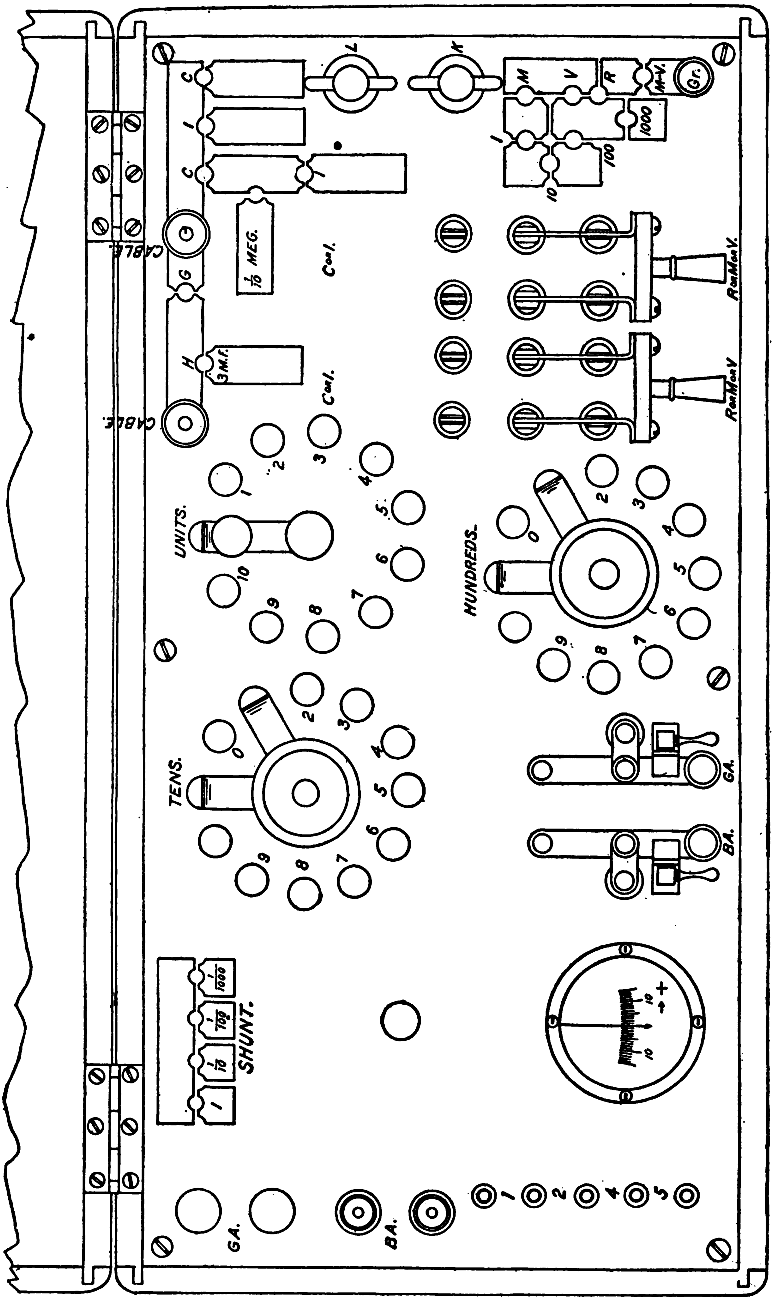


Fig. 11-30.—LONG SUBMARINE CABLES, TESTING, FISHER CABLE TESTING SET NO. 2, ARRANGEMENT OF APPARATUS.

They are connected to the ends of the row of coils below them, so that these two coils are shunted with the entire row of coils below. Consider now the result of this shunting in the case of the "Tens" and "Units" coils. The tens are, for example, 11 coils of 80 ohms each. The units are 10 coils of 16 ohms each. The two 80-ohm coils between the points 2 and 4 are shunted with the 10 16-ohm coils; 160 ohms is shunted with 160 ohms, and the resistance between the points 2 and 4 becomes 80 instead of 160 ohms. There are in the "Tens" series, for any position of the double arms, actually 10 resistances of 80 ohms each. The point of galvanometer contact may be placed at any position in the "Units" series, thus subdividing the shunted coils in the "Tens" series to tenths. The coils in the "Hundreds" series are 400 ohms each, and are subdivided in the same way by those in the "Tens"

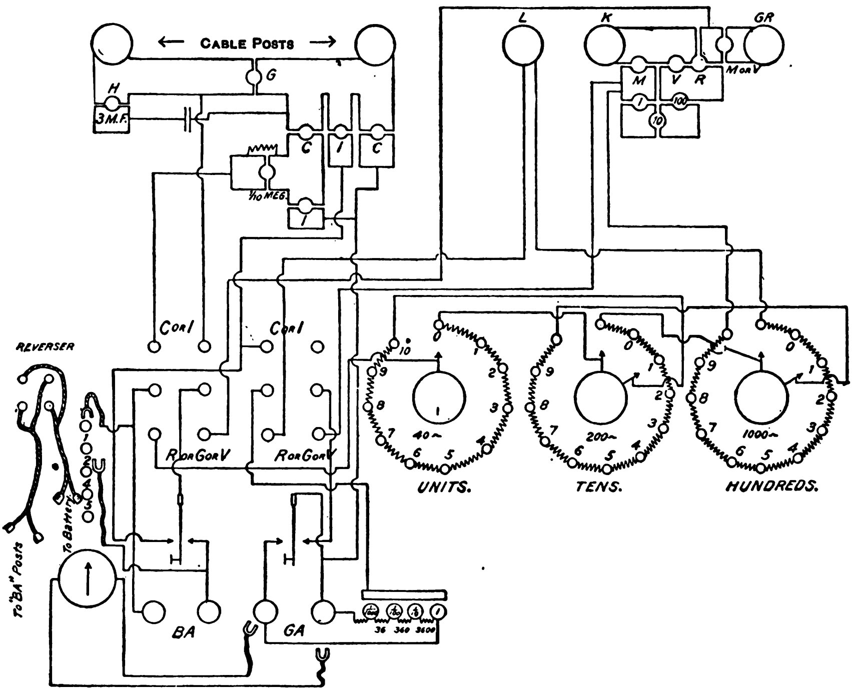


Fig. 11-31.—LONG SUBMARINE CABLES, TESTING, FISHER CABLE TESTING SET NO. 2 CONNECTIONS.

series. An example will make the use of the bridge clear. Assume that a balance is obtained with 100 unplugged in the rheostat and the contacts in the position shown. The bridge reading is then 237. Call this value A. Then

$$X:R::A:1{,}000-A, \text{ and } X=R\frac{A}{1{,}000-A}=100\tfrac{237}{763}=31.06.$$

The calculation of the fraction $\frac{237}{763}$ would take considerable time and might lead to errors. To overcome the necessity for this we furnish, conveniently fastened into the lid of each set, a table giving the values of $\frac{A}{1{,}000-A}$ for all values of A between 0 and 1,000. Reference to the table shows $\frac{A}{1{,}000-A}=0.3106$ for $A=237$. We have, consequently, simply to multiply the value taken from the table by the resistance unplugged in the rheostat to determine the value of *X*. From this it will be seen the Wheatstone bridge measurements may be made and calculated very rapidly.

In the actual construction the coils are arranged in three dials. The contact arms and points are constructed so as to insure good contacts.

From the plan (fig. 11–30) and the diagram (fig. 11–31) the arrangement and connection of the different instruments making up the set will be evident. Complete information in regard to the measurements for which the set may be used can be obtained from the following directions:

MEASUREMENTS OF ELECTROSTATIC CAPACITY.

In making tests of this nature a reflecting galvanometer should be employed, because the galvanometer of the testing set is not sufficiently accurate, nor has it a long enough scale to give good results. A reflecting galvanometer should therefore be connected to the posts marked *Ga*. (Figs. 11–30 and 11–31.)

A few cells of battery can be connected to the posts *Ba* by means of the flexible cords which come out through the hard rubber opposite said posts. If a larger battery is required the flexible cords should be disconnected from the battery of the set and connection from any other battery made to the

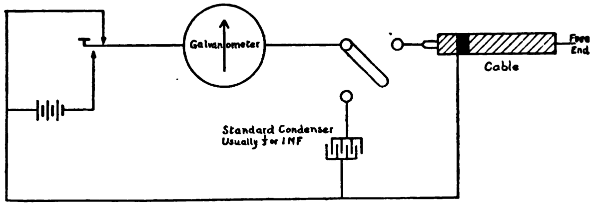


Fig. 11–32.—LONG SUBMARINE CABLES, TESTING, MEASURING ELECTROSTATIC CAPACITY, SIMPLIFIED DIAGRAM.

posts marked *Ba*. Connect the two leading wires running from the conductor of the cable and from the ground to "cable posts" and insert a plug in the hole marked 1 of the shunt. Place the handles of the two double-throw switches in the direction of the letters marked "*C* or *I*". In this test the key marked *Ba* serves to close the battery circuit, the contact point being held in place by the finger or by pressing down the cam lever at the side of the key. The key marked *Ga* serves as a short-circuit key in this test, and the short circuit is removed from the galvanometer by pressing the key down or by the use of the cam lever. Insert two plugs in the holes marked *C*, and be sure that no plugs are inserted in the holes marked *I* nor in the hole marked *G*.

The test can now be made in the ordinary manner, as follows:

Press down the key marked *Ba* for about 10 seconds, or whatever the required time of charging may be, and the instant before releasing it press down the key marked *Ga* to remove the short circuit from the galvanometer. Then the *Ba* key can be released and the discharge deflection of the galvanometer read. If it is too small, apply more battery until a sufficiently large deflection is obtained, which record. Next disconnect the cable lead wires from the conductor and in like manner measure the discharge deflection due to the leading wires. Then, without in any way changing or disconnecting the leading wires, insert a plug at *H* to connect the 0.3 microfarad condenser across the cable posts, and in like manner read the discharge deflection of the condenser. It is not necessary to jam the plug too tightly in place, because in doing so the hard-rubber posts may be strained.

To obtain the true discharge deflection of cable and condenser, subtract the discharge deflection due to the leading wires from the observed discharge deflection of cable and condenser.

Deflections are proportional to the capacities; the proportion is direct. Then letting

MF=Microfards.
N=Number of cells.
M=Multiplying power of shunt.
K=Capacity and D=Deflection of known capacity discharge.
X=Capacity and D'=Deflection of unknown capacity discharge.
L=Length of cable in feet.

Then—$K : X :: D : D'$

Hence X, the absolute capacity $=\frac{KD'}{D}$

L feet $: \frac{KD'}{D} ::$ 5,280 feet, or 1 mile $: X$ capacity per mile

Hence capacity per mile$=\frac{K \times D' \times 5{,}280}{D \times L}$

In order to prevent the E. M. F. of the battery from changing in case of a test being made when the leading wires were accidentally crossed or the cable grounded, the cable or condenser is normally charged through the $\frac{1}{10}$ megohm box, but, if desirable, said resistance can be cut out of circuit by inserting a plug in the hole marked $\frac{1}{10}$ megohm. This, however, is not recommended, as experience shows that on short cables it has little or no effect. However, in measuring the capacity of long cables, the $\frac{1}{10}$ megohm should be removed, as it has a retarding effect on the charge and discharge of the comparatively large current involved.

NOTES ON CAPACITY MEASUREMENTS FROM STANDARD UNDERGROUND CABLE CO.'S HANDBOOK NO. XVII, 1906.

With telephone cables there are two methods of making the connection for tests of electrostatic capacity:

(1) The regular or old trade standard method of testing to ground, with the connections made in the same manner as for a test of insulation resistance, namely, one wire against the remaining wires grounded to the sheath.

(2) An entirely different test for mutual electrostatic capacity, in which one wire is measured against its mate, the remaining wires being grounded to the sheath.

The electrostatic capacity by the last method of connections is the least, being about two-thirds the capacity by the former method of connections.

The use of the shunt has already been thoroughly explained, and if necessary can be used in this work, but for very accurate determinations, unless it is calibrated especially for capacity tests, it can not be relied upon, because the self-induction of the shunt does not generally bear the right relation to the self-induction of the galvanometer, so that the sudden discharge current will not divide in both circuits in the same ratio that it would for steady currents. If the condenser capacity is limited so that it can not be made comparatively near the capacity of the cable, good results can be obtained by subdividing the battery for whichever has the largest capacity. For instance, let us suppose that the condenser has four times the capacity of the cable, then we should divide the battery into about four equal parts and take the discharge deflection of the condenser for each of these, use the sum of the above, which represents the discharge deflection that would have been obtained had the full battery been used and were the galvanometer scale long enough to read the deflection. The full battery should then be used to obtain the discharge deflection of the cable. If the cable has the larger capacity, the operation should be reversed.

MEASUREMENTS OF INSULATION RESISTANCE.

In making the measurements of insulation resistance a reflecting galvanometer can be used by connecting it to the posts marked *Ga* (figs. 11–30 and 11–31) and disconnecting the flexible leads adjacent thereto which run to the horizontal galvanometer, or when approximate tests have to be made the galvanometer of the set can be employed by connecting the above-mentioned flexible leads to the post marked *Ga.* In like manner an auxiliary battery can be connected to the posts marked *Ba,* or the battery of the testing set can be employed by connecting the number of cells required to the flexible cords adjacent to *Ba.* Use small battery at first and gradually increase it until a suitable deflection is obtained. After making the connections indicated above the handles of the two

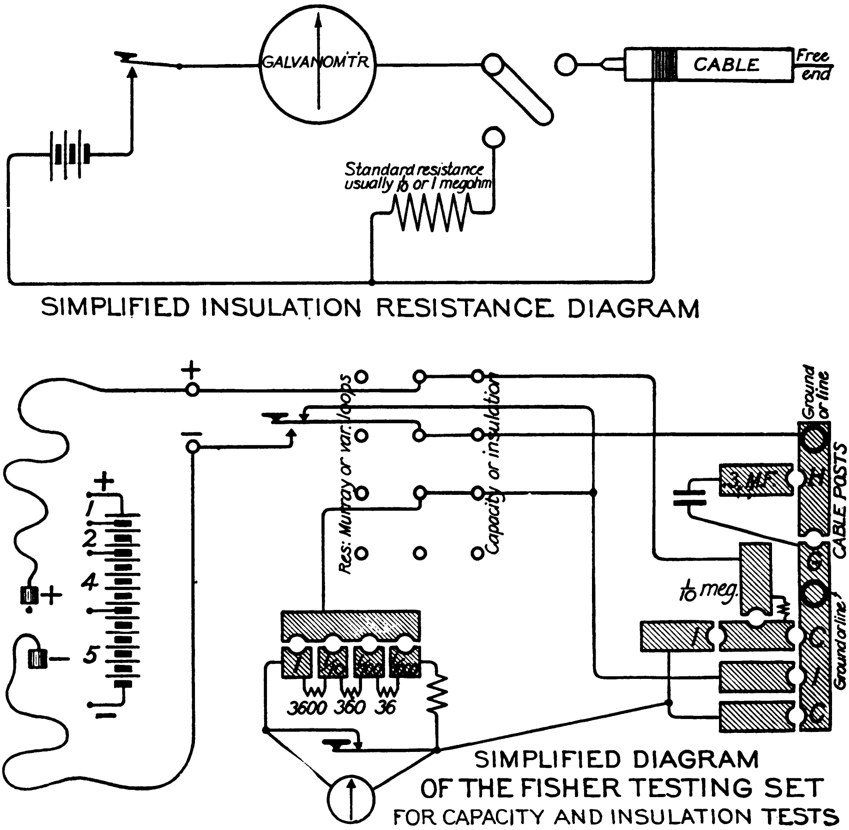


Fig. 11–33.—LONG SUBMARINE CABLES, TESTING, MEASURING INSULATION RESISTANCE, SIMPLIFIED DIAGRAMS.

double-pole double-throw switches are placed in the direction of the letters "*C* or *I*". The two leading wires from the cable conductor and from the ground are connected to "cable posts." Insert plugs into the two holes marked *I* and see that no plugs are inserted in the holes marked *C*, *G*, and *H*. The test can now be made in the ordinary manner, as follows:

Close the battery circuit by means of the key *Ba* and its accompanying holding-down cam. Shortly before the period of electrification, which is generally one minute, has elapsed, press down the key marked *Ga* to remove the short circuit from the galvanometer, when the deflection can be read. Then disconnect the leading wires from the cable conductor and in like manner measure the deflection due to the leading wires, which must be subtracted from the observed deflection first read to give the true deflection due to the cable.

At first use $\frac{1}{1000}$ shunt, gradually decreasing the shunt to 1.

In taking the constant with Fisher's set the presumption is that the same number of cells is used both in taking the constant and in measuring the unknown insulation; consequently the number of cells is not considered in the formula. Where it is necessary to vary the number of cells, the voltage in each case must be taken into consideration. This is thoroughly explained in chapter 4 of this manual.

The insulation constant of the galvanometer is next determined, as follows: The deflection is taken through 100,000 ohms or $\frac{1}{10}$ of a megohm, therefore remove the plug from the hole marked $\frac{1}{10}$ megohm and insert a plug at *G*. Use whatever shunt will give the best readable deflection, which we will call *D*. Then the insulation constant of galvanometer $= \frac{D}{10 \times \text{shunt used}} = G$

G=Galvanometer constant, or deflection through 1 megohm.

D=Deflection through $\frac{1}{10}$ meghom.

M=Multiplying power of shunt.

Large deflection : Small deflection : : Large resistance : Small resistance.

$D \times M$: G : : 1 megohm : $\frac{1}{10}$ megohm.

$G = D \times M \times \frac{1}{10}$.

Let D'=Deflection due to the cable.

L=Length of cable in feet.

Absolute insulation resistance of the cable $= \frac{G}{D' + M}$.

For: Large resistance : Small resistance : : Large deflection : Small deflection.

Absolute resistance : 1 megohm : : G : $D' \times M$.

If absolute resistance is less than 1 megohm, the words "Large" and "Small" in above proportion should be reversed.

Insulation inverse to distance—

Large distance : Small distance : : Large per mile insulation : Small absolute insulation

L feet : 5,280 feet : : per mile insulation : $\frac{G}{D \times M}$

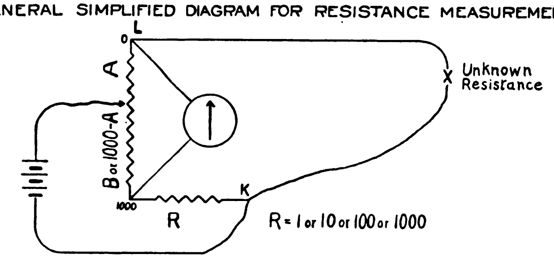
Insulation per mile $= \frac{GL}{D \times M \times 5{,}280}$

It is best to make the regular insulation resistance test with the $\frac{1}{10}$ megohm in series, and this is done by removing the plug from the hole marked $\frac{1}{10}$ megohm. This is advised so that the battery can never be short-circuited. Where great accuracy is desired the $\frac{1}{10}$ megohm can be subtracted from the calculated absolute insulation resistance to get the true insulation resistance.

MEASUREMENTS OF CONDUCTOR RESISTANCE.

Place the handles of the two double-pole double-throw switches in the direction "*R* or *M* or *V*", figure 11–31, insert a plug in the hole marked *R*, and at the same time see that no plugs are in the holes marked *M* or *V*. It will be noted that there are four resistances, viz, 1, 10, 100, 1,000 ohms. Any one of these can be used in the test by removing its corresponding plug and inserting plugs in the other three holes. Before commencing the test a resistance near to the probable resistance to be measured should be left unplugged. For instance, if 5 ohms or less have to be measured the 1 ohm resistance should be left

GENERAL SIMPLIFIED DIAGRAM FOR RESISTANCE MEASUREMENT



Simplified Diagram of the Fisher's Testing Set for Resistance, Murray Loop and Varley Loop Tests

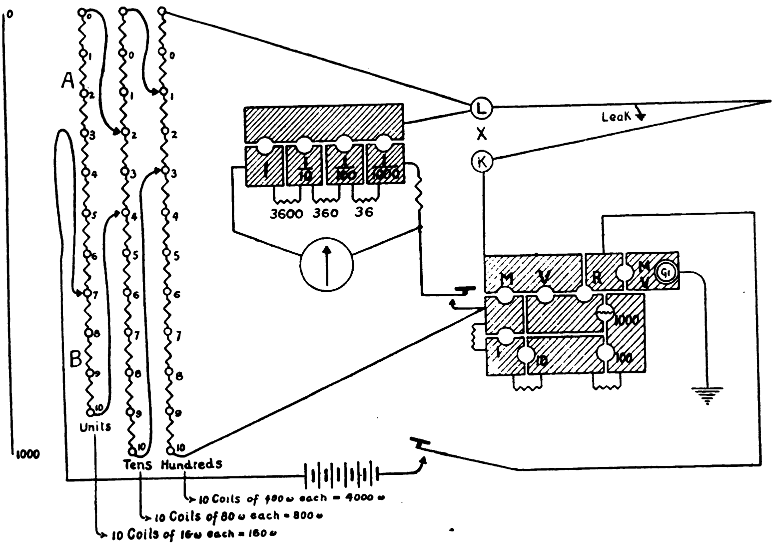


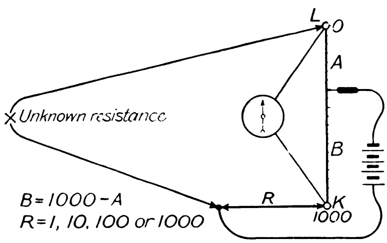
Fig. 11–34.—LONG SUBMARINE CABLES, TESTING, COPPER RESISTANCE, MURRAY AND VARLEY LOOP, SIMPLIFIED DIAGRAM.

unplugged. If the probable resistance to be measured lies between 5 and 50 ohms the 10 ohms resistance should be left unplugged; if the resistance to be measured is over 50 ohms the 100 ohms resistance should be left unplugged.

Connect in the resistance to be measured to the posts *L* and *K*. By means of the flexible cords opposite the posts marked *Ba* connect a few cells of battery at first, and if necessary the whole 12 cells later. Connect the flexible cords opposite the posts marked *Ga* to said posts. For the commencement of the test use $\frac{1}{1000}$ shunt, decreasing shunt by steps to 1.

The test can now be made by first placing the arms of the "Tens" and "Units" dials at zero and moving the "Hundreds" dial to 5. Press down first the battery key and instantly thereafter the galvanometer key, and note the direction in which the galvanometer pointer moves. If the battery flexible cords have been connected as indicated by the corresponding plus and minus signs, a deflection of the galvanometer toward the plus sign indicates that the dial resistance must be increased, while if the deflection is in the opposite direction, the dial resistance must be decreased. With this information in mind an instant only is required to determine between which two sets of "Hundreds" the balance point lies. Having found this, place the pointer at the lowest of the two, and in like manner determine between which two sets of "Tens" the balance point lies, placing the switch at the lowest of these. The final balance can then be found by rotating the "Units" switch until a point is reached when there is no deflection of the galvanometer. With the "Tens" and "Hundreds" switches the reading is taken between the two contact arms, while with the "Units" switch the reading is taken at the segment with which the rotating arms is in contact.

Note.—In using Fisher's Set, for Resistances, or Murray & Varely loop test, it is always best to keep the simplified diagram before the tester's eyes, as it facilitates thorough understanding. This diagram can be roughly drawn in less than one minute.



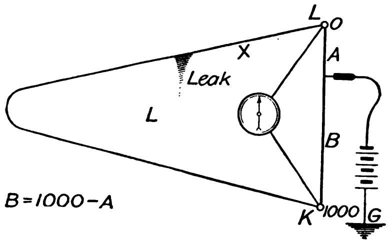
Letting R = the unplugged resistance to the right of the double switches.
Letting A = the reading of the dial switches arranged in the order of hundreds, tens, units,

$$A:X::1{,}000-A:R \therefore X=\frac{AR}{1{,}000-A}$$ ohms the resistance to be measured.

The value of the term $\frac{A}{1{,}000-A}$ can be found in the accompanying table, when it is only necessary to multiply said value by the amount of resistance unplugged.

MURRAY LOOP METHOD OF LOCATING GROUNDED OR CROSSED WIRES.

This is the simplest method of locating grounds or crosses, and is chiefly applicable when the faulty and good wire are of the same size and length; hence it can be used to locate such faults in telephone and telegraph cables where all the conductors seldom become faulty before the method can be applied. It can also be used in the case of an electric cable where the outgoing and incoming cable are the same size and length and where one of them is not faulty. To apply this method, join the faulty and good conductor at the distant end of the cable and connect the faulty conductor to *L* and the good conductor to *K*. Place the two double-throw double-pole switches in the direction of "*R* or *M* or *V*", insert plugs in the two holes marked *M*, and be sure that no plugs are in the two holes marked, respectively, *V* and *R*. The resistances 1, 10, and 100 can be either plugged or unplugged without affecting the test. Connect the ground, or in the case of a cross the wire crossed with the one used in the test, to the post marked *Gr*. The galvanometer and battery are connected in the same manner described under "Measurements of conductor resistance." The description there giving the operating of dial switches is exactly the same as must be followed in this case.



Part : Whole : : Part : Whole

$A:1{,}000 \;::\; X: \quad L$ or whole loop $\therefore X=\frac{AL}{1{,}000}$

Letting A=the reading of the dials which gives a balance of the galvanometer.

L=the total length of the circuit=twice the length of the cable if the good and bad wires are in the same cable. The length can be in inches, feet, yards, miles, or ohms, and X, the result, will be in the denomination used.

Then,

The distance to the fault from the post $L=\frac{A\times L}{1000}$

The check method can now be applied by connecting the faulty conductor to K and the good conductor to L.

Letting A'= the reading of the dials, which gives a balance. $1{,}000-A'$ should $=A$, which substitute in the above equation for A, which gives $\frac{1000-A'}{1000}\times L$ the distance to the fault by the check method, which should be the same as before.

Another method of checking the accuracy of the result is that in every case AA' should equal 1,000.

When dealing with faults of high resistance, 50 or more cells of battery may have to be used. The battery should be connected to the posts *Ba*, and the corresponding flexible cords should be disconnected from the battery of the set.

The Murray loop may be used where the two wires constituting the loop are of different kinds and resistances. First measure resistance of loop, then take a Murray loop test, when X will be found in ohms; convert X into distance by reference to wire tables.

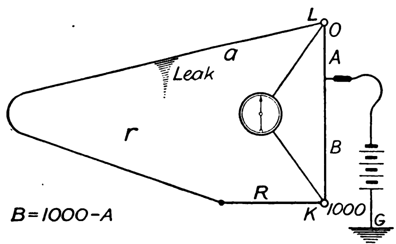
VARLEY LOOP METHOD OF LOCATING GROUNDED OR CROSSED WIRES.

The Murray loop method is preferable to the Varley loop method with the Fisher's set, for with the Murray loop no extra resistance *R* is added, nor is it required; while the Varley loop test calls for extra resistance *R* and its elimination, with no increase in efficiency to compensate for the extra labor.

Join the faulty and good conductor at the distant end of the cable, and at the near end of the cable connect the former to the post marked *L* and the latter to the post marked *K*. Then measure the resistance of the circuit as described under "Measurements of conductor resistance."

Let r=said resistance.

Place the handles of the two double-throw double-pole switches in the direction of "*R* or *M* or *V*". Insert plugs in the two holes marked *V*, and see that no plugs are in the two holes marked, respectively, *M* and *R*. Join the faulty and good wires at the distant end of the cable and connect the former to *L* and the latter to *K;* connect the ground or, in the case of a cross, the wire crossed with the one used in the test, to the post marked *Gr;* unplug the resistance marked 100 and plug the resistance marked 1 and 10, connect the battery and galvanometer and operate the dial switches in the same manner described under "Measurements of conductor resistance." If the balance can not readily be obtained, it may be necessary to unplug the 10-ohm or perhaps the 1-ohm; the other two resistances must, of course, be plugged. The dial switches are now operated, as described under "Measurements of conductor resistance," until a balance is obtained, when the reading is recorded.



Let R=the resistance unplugged in the rheostat,

Let r=the resistance of the faulty and good wires,

Let A=the reading of the dials which gives a balance of the galvanometer, and,

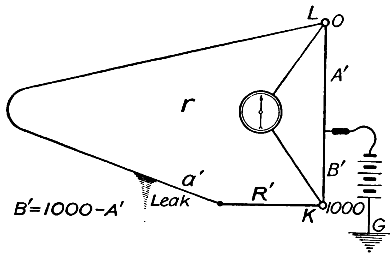
Let $B=1{,}000-A$,

Let a=the resistance to the fault from L,

$$A:1{,}000::a \text{ ohms}:r+R(\text{ohms}) \therefore 1{,}000a=Ar\times Ar \therefore a=\frac{A(r+R)}{1{,}000} \text{ ohms}$$

CHECK METHOD.

Connect now the faulty wire to *K* and the good wire to *L*, and proceed in the same manner to find the new values *A*, *B*, *R*, and *a*, which for the check method we will call A', B', R', and a'.



The resistance to the fault from;

$$B':1{,}000::(R'+a'):(R'+r)$$

$$1{,}000a'+1{,}000R'=B'R'+B'r \therefore 1{,}000a'=B'r+B'R'-1{,}000R'$$

As $B'=1{,}000-A'$ substitute it for B'

Hence: $1{,}000a'=B'r+1{,}000R'-A'R'-1{,}000R'$

$a'=\frac{B'r-A'R'}{1{,}000}$ ohms. Answer, which should be the same as found for "a" above.

Let b=the resistance of the faulty wire=one-half the resistance of the loop where good and bad wires are of the same size and are in one cable.

Let L=the length of cable.

Then,

a ohms as found above : b ohms :: X, the distance to the fault by first method : L

Hence—

$$X=\frac{aL}{b}$$

a' ohms as found above : b ohms :: X the distance to the fault by check method : L

Hence: $X=\frac{a'L}{b}$ which should equal $\frac{aL}{b}$

a ohms should equal a' ohms.

ARRANGEMENT OF TESTING SET.

The convenient arrangement of the testing set at the cable office is of great importance. Not only does this make tests easy, but it tends to accuracy as well, since troubles are easily traced in sets where the wiring is well laid out and all parts of instruments easy of access.

The wiring should invariably be done with best rubber-covered wire or, better, cable core, supported on porcelain cleats or knobs. The layout of the instruments on the table is shown in figure 11–35. The galvanometer should be on a separate shelf not connected with the table. It should be about the height of the shoulder from the floor. On the opposite end of the table the lamp and scale are supported at the same height on a shelf or stand separate from the table. By this arrangement of the galvanometer, lamp, and scale, the scale is in full view while the Wheatstone bridges or keys are being manipulated.

The galvanometer lamp is usually an electric lamp, with a straight filament, placed behind the slit in the scale, and the concave galvanometer mirror reflects an image of the filament as a brilliant vertical line on the scale, when the scale and galvanometer are the proper distance apart for correct focusing. If electric light is not available, an oil lamp may be used.

EXCESSIVE E. M. F. NOT TO BE USED.

After a cable is laid, the E. M. F. used in testing should not exceed 40 volts, except when necessary to obtain the required current in locating breaks, when a reasonable increased voltage may be used, but should be applied to the cable the shortest time possible to obtain desired results.

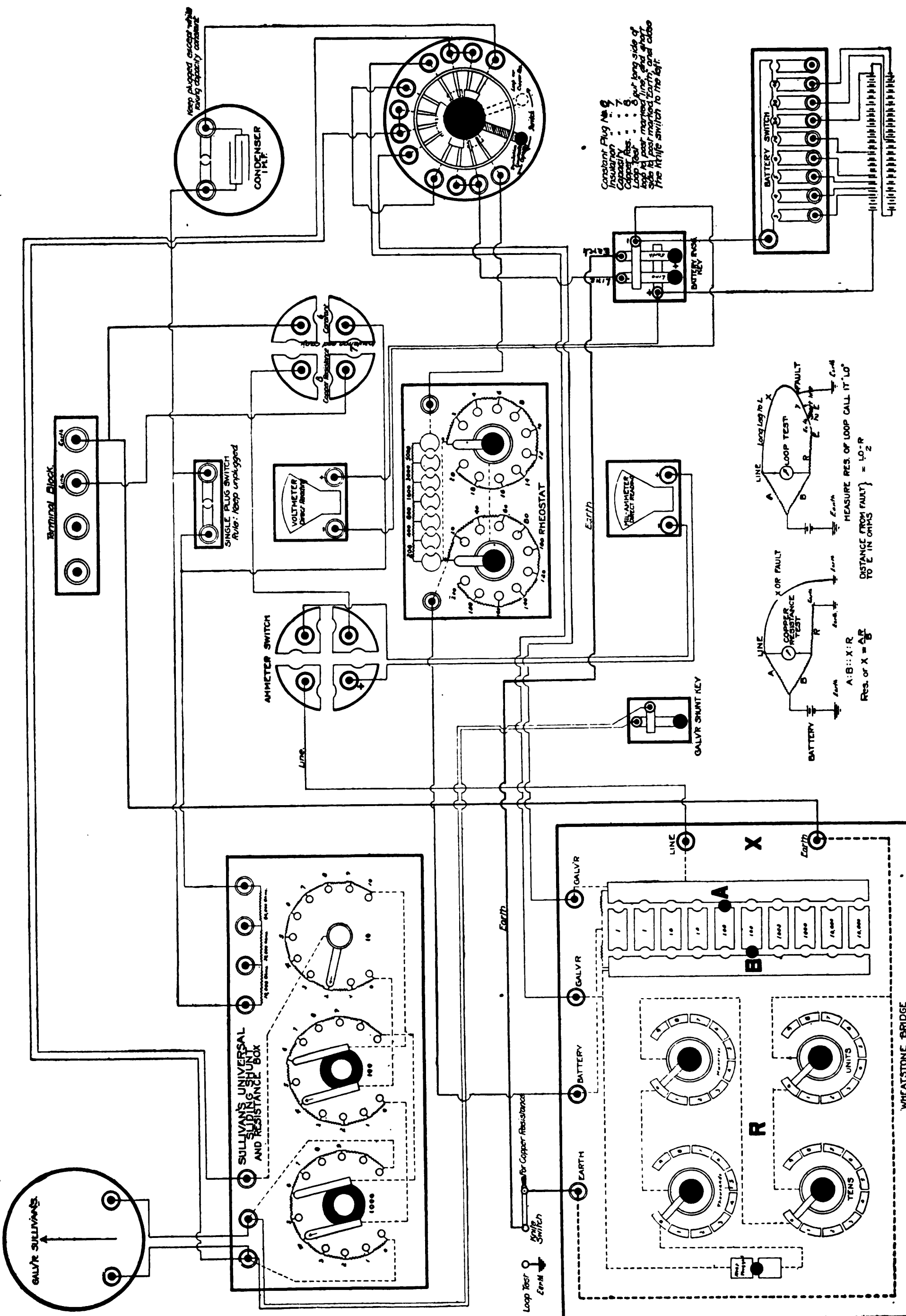


Fig. 11-35.—LONG SUBMARINE CABLES, TESTING, PLAN OF TESTING TABLE, SEATTLE CABLE OFFICE.

The resistance box, adjustable from 2 to 11,220 ohms, shown in figure 11–35, is used in the battery circuit when making bridge measurements, and readily permits adjustment to the proper current strength as shown on the milliammeter.

For locating high resistance leaks, when sufficient variation of the current by using reasonable voltage can not be obtained, recourse must be had to Clark's potential test, or Jordan & Schonau's modification of the earth overlap test appearing later in this chapter.

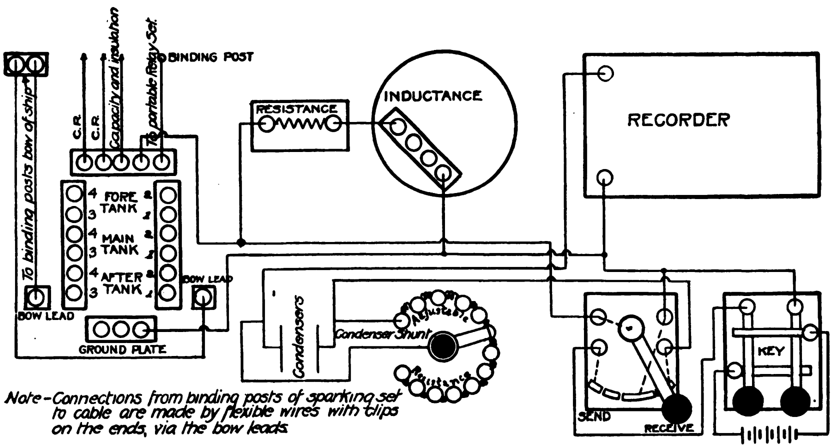


DIAGRAM OF SPEAKING CONNECTIONS, U.S.A.T. BURNSIDE.

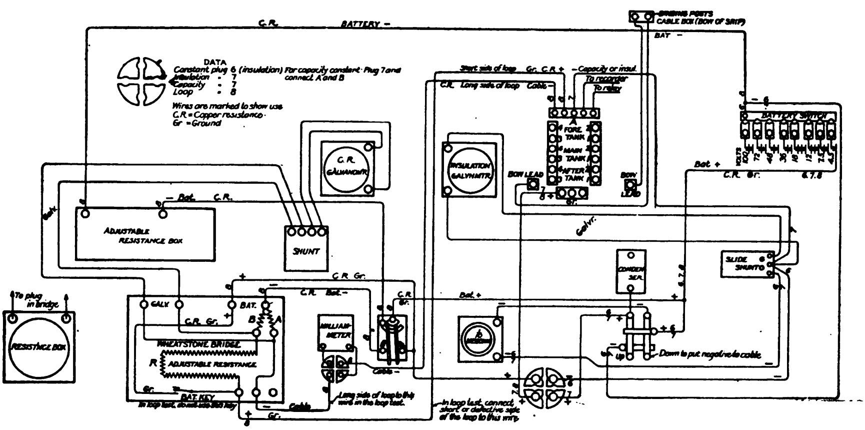


Fig. 11–36.—LONG SUBMARINE CABLES, TESTING, TEST ROOM CONNECTIONS, U. S. A. T. BURNSIDE.

Care must be taken in the insulation test not to depress short-circuit key until cable has been charged for 10 or 15 seconds.

To get capacity indications on galvanometer the amount of "throw" of galvanometer on opening or closing reversing key *with the short-circuit key depressed* will give the capacity, provided the amount of this throw is compared with that given by a condenser of known capacity connected in place of line and earth, when battery and shunt are the same in both cases.

It must be understood that this method gives reliable indications only with comparatively short cables. For long cables Gott's test, described at length in the books of reference, should be employed.

In all measurements let the rule be to begin with a large shunt and small battery, gradually increasing the battery and gradually decreasing the shunt. This method will prevent damage to the instrument.

LOCATION OF FAULTS IN SUBMARINE CABLES.

The application of the measurements just described in the location of faults may now be dealt with. The more complete exposition of the subject in the books of reference cited is recommended to those who desire to go into the matter more deeply.

Faults on cables are similar in nature to those on land lines. When the cable is completely ruptured faults may be described under the following headings of Class I:

Class I: First. The conductor is in contact with the metal sheathing and is "dead grounded."

Second. The conductor is considerably exposed by much of the insulation at and near the end being broken away.

Third. When the end of the conductor is only partially exposed or deeply buried in mud and sand.

Fourth. When the insulating material is drawn well over the broken end of the conductor almost completely insulating it.

Class II: Conductor ruptured; insulation remaining intact.

Class III: Break or abrasion of the insulating material, causing either a high-resistance leak (escape) or one approximating to a "dead ground," depending upon the amount of exposure of the conductor.

The behavior of the fault under working conditions or test will usually determine to which class it belongs.

Rupture of the cable is attended, of course, with total cessation of signals from the distant end, and this usually occurs suddenly. The end of the conductor is generally left more or less exposed. If left much exposed, or grounded on the cable armor, the galvanometer will indicate a comparatively steady current when moderate battery power is applied. If the exposure is small, or the end is buried in mud, great fluctuations in the current will be produced, and greatly different when different ends of the battery are placed to line. If the conductor is well drawn back into the insulation, or the conductor is ruptured inside the insulating covering, of course nothing but the transitory current of charge and discharge will be observed.

Damage to the insulation, exposing more or less of the conductor, very frequently is first noted as a "leak," which becomes worse and worse, until communication is interrupted. Unless the damage is extensive, the reception of feeble signals from the distant station will disclose that the fault belongs to Class III and that the cable is not ruptured.

In locaing the first of Class I it is evident that it requires only the measurement of the copper resistance. This divided by the resistance per mile will locate the fault. In No. 4 of Class I and in Class II a measurement of capacity is required. This divided by capacity per mile gives the distance.

In all the others where partial exposure of the conductor is involved and only one end is available at the testing room, localization is difficult, owing to the polarization at the fault and its consequent change of resistance with different strengths and directions of current. When faults are minute this polarization changes resistances from a few ohms to thousands, and vice versa, with such rapidity as to require the greatest skill and judgment in testing. In general, by putting zinc to line, the generation of hydrogen and consequent cleansing from metallic salts at the fault tends to open it up; while putting carbon or copper to line, by coating the fault with chloride of copper, will cause the resistance to rise by sealing up the fault.

If the defect in insulation is small it is sometimes difficult to detect which pole causes the most rapid polarization.

When the cable is coiled in the tanks, where both ends are available, or when two cables have been laid between two points permitting their looping at the far end, or when the cable has multiple cores one or more of which remain uninjured, faults in the insulation of a cable, where the conductor is not broken, may be quite accurately and easily located by the "loop test." This being the simplest method of locating these faults in cable, it will be dealt with first.

First measure the resistance of the loop which we will call L with the two ends of the conductor connected to the Wheatstone bridge. Then change the connection, as shown in figure 11–37.

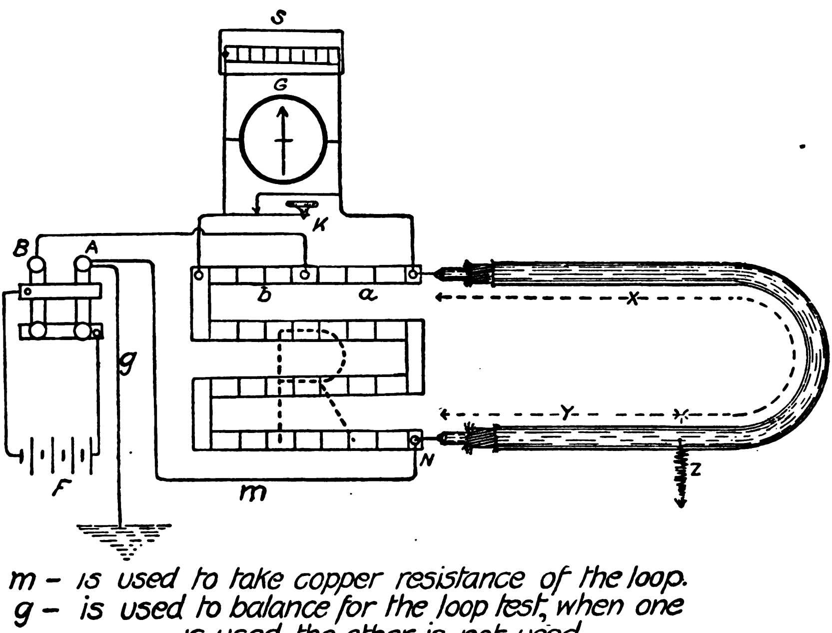


Fig. 11–37.—LONG SUBMARINE CABLES, TESTING, LOCATION OF GROUND, SIMPLE LOOP TEST, CONNECTIONS.

It will be noted that the end with small resistance between it and the fault Y must be connected with N, otherwise no balance can be obtained. When this is found to be the case transpose the ends. When balance is obtained call the values in balance arms a and b and amount unplugged in resistance R, as noted in diagram.

$a : a+b :: X : L+R$ or Part : Whole :: Part : Whole, which is similar to the loop proportions for the Fisher's set previously shown, Hence—

$$X=\frac{a(L+R)}{a+b}$$

When—

$$a=b \text{ we have } X=\frac{a(L+R)}{2a} \text{ or } X=\frac{L+R}{2}$$

To find the value of Y, use this proportion, i. e.,

$b: b+a :: Y+R: L+R$

or Part : Whole : : Part : Whole

Hence—

$$bY+bR+aY+aR=bL+bR$$
$$Y(a+b)=bL+bR-aR-bR: \ -bR \text{ and } +bR \text{ cancel,}$$

Then—

$$Y(a+b)=bL-aR \text{ and } Y=\frac{bL-aR}{a+b}$$

When—

$$a=b, \text{ then } Y=a\frac{(L-R)}{2a} \text{ hence } Y=\frac{L-R}{2}$$

A simple inspection of the preceding diagram shows these formulæ to be correct.

When the break is of the second or third kind, under Class I, it is usually indicated by more or less rapid polarization when the copper or carbon pole is put to line; that is, by a rise of resistance. The fact that it is a break is indicated by the cessation of even feeble signals from the distant station. Sudden variations or jumps of resistance when the battery is applied indicates that the conductor is only partially exposed, or that it is deeply buried in mud or sand, thus preventing free escape of the gases liberated by electrolysis.

One of the successful methods of testing through the exposed end of the conductor at a total break and obtaining the copper resistance up to the break is that devised by Prof. Kennelly. This method of eliminating the resistance of the exposed end itself depends upon the fact that the resistance of the fault varies inversely as the square root of the current strength passing through it, provided the exposure is not less than half of a square centimeter.

Supposing the current through the break be increased four times, the apparent resistance will be decreased one-half, for $\sqrt{4}=2$ and inversely is 1/2. The strength of the current should in no case, however, exceed 25 milliamperes. The measurements should be made by the false zero method, using zinc (negative current) to line.

The usual arrangement of the Wheatstone bridge for copper resistance is made. See simplified diagram for conductor resistance measurements, figure 11–38, and diagram of test sets at cable offices, Washington-Alaska system, figure 11–35. If X be the resistance up to the break, A the resistance obtained by measurement with, say, 4 milliamperes, B with 16 milliamperes being four times as many as with A, then, using Kennelly two-current false zero formula,

Let X=resistance of the cable to the break,

Let Y=resistance of the fault,

Then—

$A=X+Y$,

$B=X+1/2Y$ (multiply both members by 2).

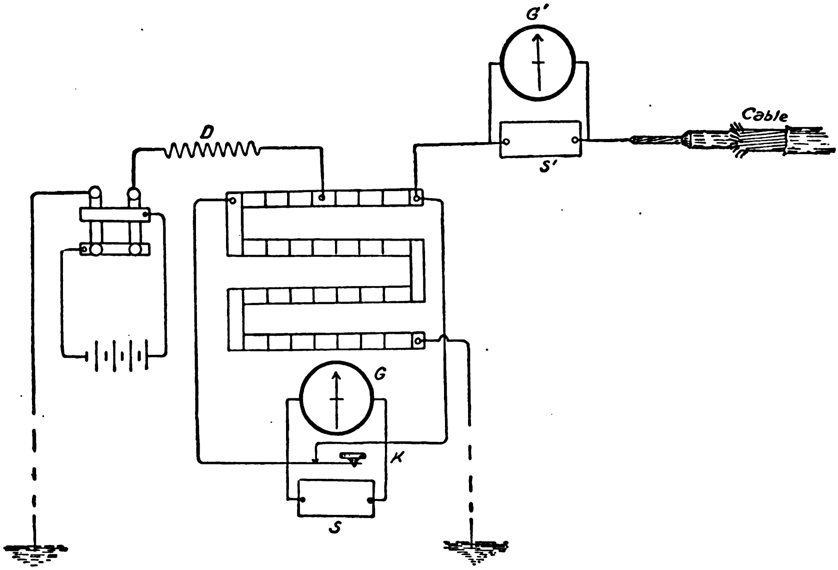
We have—

$2B=2X+Y$, subtracting first equation.

$A=X+Y$.

$2B-A=X$, the reistance of the cable to the break.

For example, if the measurement with 4 milliamperes gave 1,650 ohms, and with 16 milliamperes 1,560 ohms, the resistance up to the break is 1,560×2—1,650=1,470 ohms. Greater exactness can be secured by taking the exact ratio of currents going to line by inserting a milliammeter between the bridge and the cable. These ratios can be inserted in the general formula. For this formula and the general discussion of the method, reference is made to the works cited at the beginning of this chapter.



ig. 11-38.—LONG SUBMARINE CABLES, TESTING, LOCATION OF GROUND, PROFESSOR KENNELLY'S METHOD, COPPER RESISTANCE CONNECTIONS.

Simplicity is a large factor in the rapid work necessary on a cable ship, and it has been found by experience that tests based on a variation of currents, with resultant effects on the resistance of the fault, are the best. The Jona curve is based on variations of current; the regularity of the curve shows the dependence to be placed on the tests; the tests have the advantage of scale zero; besides, data are furnished for solving a number of other scale-zero formulæ if it is so desired.

Testing in a jar of sea water on a desk, with every advantage and no earth currents, will show how difficult it is to locate faults with absolute accuracy.

Absolutely accurate locations of faults also can not be made on account of the following: Errors made in location of cable when it is originally laid in the open sea; difficulty in calculating for the extra slack cable paid out when the cable is in process of laying.

In general, the location of faults of Class III presents the greatest difficulty. Of course, if a second and sound cable or another sound core in same cable joining the two places is available, the distant ends are looped, and the reliable "loop test" may be used.

And when the exposure of the conductor is considerable, making the fault resistance so low that not any or barely perceptible signals can be obtained from the distant station, Jona curve and formulæ, based on Jona curve, scale zero data may be applied, the distant end being insulated.

No other very satisfactory method exists of locating leaks (escapes) on cables when facilities exist for taking measurements at one end only.

CLARK'S POTENTIAL TEST.

[See Baines' Manual.]

This depends on the principle that in any circuit with resistances in series the fall of potential at any point is proportional to the resistance passed over, beginning at the high potential terminal. The instruments required at the main station are a delicate galvanometer, high resistance up to 100,000 ohms, a Weston voltmeter, and a box of standard coils. The Wheatstone bridge will answer for the latter.

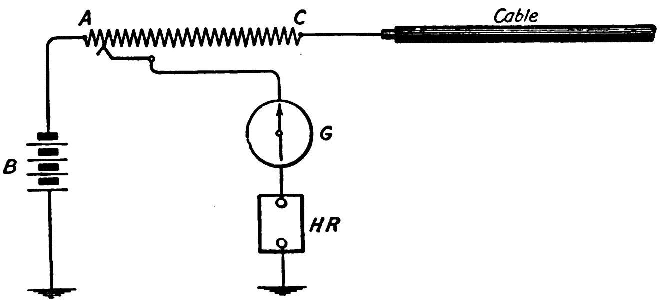


Fig. 11-39.—LONG SUBMARINE CABLES, TESTING, LOCATION OF GROUND, CLARK'S POTENTIAL TEST, CONNECTIONS.

At the far station the box of standard coils is not required. However, it is better for each to be the main station in turn and compare results.

The connections at the main station are as shown in figure 11-39.

The connections at the distant station are as shown in figure 11-40.

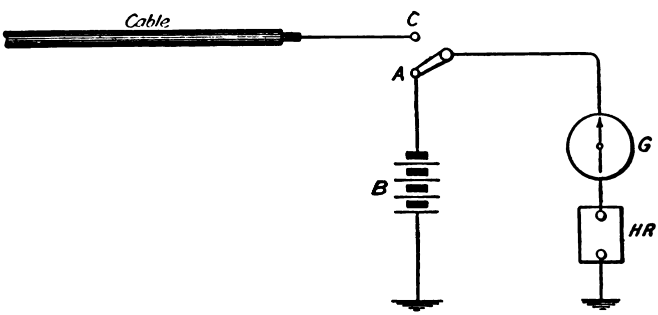


Fig. 11-40.—LONG SUBMARINE CABLES, TESTING, LOCATION OF GROUND, CLARK'S POTENTIAL TEST, CONNECTIONS AT DISTANT STATION.

Before closing the circuit the voltage of the battery B is determined with the Weston voltmeter, cell by cell, so the low reading scale may be used and the sum of these voltages taken. AC is the box of standard coils, which should be at first unplugged to a resistance approximately equal to one-half that of the cable.

The galvanometer G and high resistance HR are connected in series, as shown. The number of cells and HR should be proportioned as to give nearly a full scale reading when the galvanometer is connected with A. First take a reading at both stations with G connected with A and line open at C. This deflection will correspond to the total battery voltage as shown by the sum of readings of the voltmeter. Suppose the total number of volts is P and the deflection is D; then $\frac{D}{P}$ will give the number of divisions of the scale corresponding to one volt.

Now, disconnect batteries and connect the galvanometers with the line at each station and observe the deflections due to earth current (*E. C.*), both in *direction* and *amount*.

The main station then connects battery, standard coils, and cable, as shown in figure 11–39, and, having arranged time with distant station, they take the following readings, as nearly together as possible:

Main station takes readings, first, with G connected with A, and then with G connected with C. Distant station with switch turned to C simply reads deflection and reports it to main station. All readings are reduced to volts.

These readings are designated as V, v, and v', respectively. v and v' are then corrected for earth-current readings, adding the value of earth current if it is *against* and subtracting if it is *with* the battery current.

The distant station then sends the corrected result to main station. The formula for the solution is as follows:

x=resistance from main station to fault.

R=number of ohms unplugged at AC.

$$R : V-v :: X : v-v'.$$

$$x=\frac{R(v-v')}{V-v}.$$

For example, suppose the total voltage of battery in figure 11–39 were 11.2, and that the galvanometer through the high resistance gave a deflection of 273, then $\frac{D}{P}=\frac{273}{11.2}=24.4$ scale divisions per volt. In like manner distant station determines the value of his deflections. Suppose it is 27 divisions per volt. Earth current gives 18 divisions *against* direction of testing current at both stations.

Now, suppose V is 265 divisions, v 193 divisions, and v' 65 divisions.

R=800 ohms.

These would correspond, respectively, to

$\frac{18}{24.4}=.74$ E.C. volts at main station

$\frac{18}{27}=.67$ E.C. volts at distant station

$\frac{265}{24.4}=10.9$ volts V

$\frac{193}{24.4}=7.9$ volts v

$\frac{65}{27}=1.4$ volts v'

$7.9+.74=8.64$ corrected v

$1.4+.67=2.07$ corrected v'

Substituting in formula

$$x=\frac{800(8.64-2.07)}{10.9-8.64}=\frac{5256}{2.26}=2325 \text{ ohms}$$

If the resistance of the cable is 8.5 ohms per nautical mile, the fault is $\frac{2325}{8.5}=273.5$ miles distant from main station.

More accuracy would probably be reached by repeating the test, using a new value of R approximating to x, as found above.

One great advantage of the Clark test is that, as readings at the two ends may be made practically simultaneously, errors due to irregular polarization and earth currents are eliminated.

EARTH OVERLAP TEST.

Where both stations are equipped with full sets of instruments one of the best methods of localizing faults due to defects in insulation is called the earth overlap test. It is particularly applicable to high-resistance faults.

In effect the measurements are made with a view to determining how much resistance should be put in at the station nearest to the fault in order to make the resistances on each side of the fault equal.

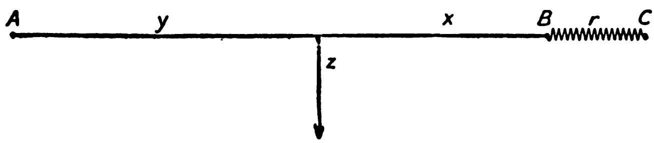


Fig. 11–41.—LONG SUBMARINE CABLES, TESTING, LOCATION OF GROUND, EARTH OVERLAP TEST, DIAGRAMMATIC.

The measurements are made by the observers alternating in measuring line resistance with distant station earthed, each allowing a specified number of minutes, say three, for each station's tests. Both should measure in the same way—that is, either with the false zero with zinc to line or with reversals. Both use the same number of cells testing battery.

Let AB be a cable with a fault in it at z (fig. 11–41). Suppose the copper resistance of the cable when sound to be known having a value, L, and the fault occurs at distance x from B.

If tests are made at the end B, it is evident that when a resistance r is inserted, making $x+r=y$, then the following equations result:

$$x+y=L;\ x+r=y$$
$$y=L-x$$

$$\therefore x+r=L-x;\ x=\frac{L-r}{2}$$

or substitute first value of y in first equation; when $x+x+r=L \therefore 2x=L-r;\ x=\frac{L-r}{2}$, same as before.

The routine is as follows: B tests first and gets, say, 2,500 ohms, then A gets 3,000 ohms. They exchange results. B now inserts a resistance which should be greater at first than the difference between the results, owing to resistance at the fault.

For example, B inserts 1,000 ohms and tests three minutes with A earthed. He then earths through the inserted resistance for three minutes and A tests.

They then compare results, the *last* at B and *first* at A being considered most reliable.

B now gets 3,800 ohms and A 3,500, so 1,000 ohms is too much. B inserts 600, 800, 650, 700, and 670 ohms in succession, going alternately too low or too high until at 670 both B and A get a mean result practically identical or about 3,500 ohms.

It is found better to go alternately too low and too high rather than twice on the same side. Also it is recommended that when nearly the same at both ends measurements should be repeated to check errors.

Supposing the resistance of the cable when sound (L) to be 4,500 ohms, then by the formula $\frac{L-r}{2}=x$

$$\frac{4500-670}{2}=1{,}915 \text{ ohms from } B \text{ to the fault.}$$

For further information concerning this test refer to Jordan's and Schonau's modification of Kenneley's and Anderson's earth-overlap test in "Handy Formulæ for Testing Submarine Cable for Breaks, Dead Grounds and Earth Overlap," appearing later in this chapter. Also see "Beginners' Manual of Submarine Cable," by Baines, page 132.

The advantage of testing by varying the current is that there need be no cooperation between distant stations; the testing is done by one man, while Clark's potential test and the earth-overlap tests require cooperation between stations, with possibility of delay and disagreement, unless well arranged for before undertaken.

However, the Clark's potential and the earth-overlap tests are particularly applicable to locating high-resistance faults, through which it would be impossible or impracticable to force enough current to vary sufficiently to form a Jona curve, or apply to formulæ using similar data.

Should the cable have more than one fault, the result found will lie somewhere between the two actual faults and nearer to the fault with the least resistance. This remark applies to all tests.

HANDY FORMULAE FOR TESTING SUBMARINE CABLE FOR BREAKS, DEAD GROUNDS, AND EARTH OVERLAP.

Location of cable faults can not be definitely made where there is not a metallic circuit. Where part of the testing current passes through water, decomposition takes place at the fault and the resistance of the fault is constantly changing.

It has been found by practice that the resistance of such a fault varies inversely as the square root of the testing current, provided the exposed surface of the conductor be not less than one-half of a square centimeter, and the testing current does not exceed 24 milliamperes.

SCALE—ZERO.

[Not metallic circuit.]

No. 1, Jona curve (see curve sheet fig. 11–42). Preferable to use exact number milliamperes, as printed on left-hand edge of sheet.

The Jona curve is based on variations of current; the regularity of the curve shows the dependence to be placed on the tests. The scale zero is used. The data may also be used for solving other scale zero formulæ. The regularity of the curve is very important. Usually the other formulæ using this data means much increased work, with little additional advantage. (See the actual test shown below.)

From the measurements for the above Jona curve, scale zero, 2 to 24 milliamperes, the following formulæ can be worked out and used for checking purposes, or in deriving a mean result.

For uniformity, the designations below of C=current and R=resistance, and their relations to each other should be maintained.

C_1=lowest current=highest resistance=R_3
C_2=intermediate current=intermediate resistance=R_2
C_3=highest current=lowest resistance=R_1

No. 2. Cann's triple-test (p. 60, Barkers Handbook, 1903):

$$\text{Current ratio: } \overset{C_1}{1} : \overset{C_2}{2} : \overset{C_3}{4} \text{ —Scale zero.}$$
$$\quad R_3 \quad R_2 \quad R_1$$
$$X=R_1+R_2-R_3$$

NOTE.—Can get six calculations from Jona measurements for the practical tests appended hereto.

Using *Ma*	*Ma*	*Ma*
2,	4 and	8
3,	6 and	12
4,	8 and	16
5,	10 and	20
6,	12 and	24
8,	16 and	32 approximating for 32.

No. 3. Rymer-Jones dual test, modification of Cann's (p. 61, Barker's Handbook, 1903).

$$\text{Current ratio: } \overset{C_1}{1} : \overset{C_2}{2} \text{ —scale zero.}$$
$$\quad R_3 \quad R_1$$
$$X=2.5576\ R_1-1.5576\ R_2$$

NOTE.—Can get eight calculations, but the two lowest are too small; possibly only one lowest too small. See practical test annexed.

Using *Ma.*	*Ma.*	Using *Ma.*	*Ma.*
2 and	4	6 and	12
3 and	6	8 and	16
4 and	8	10 and	20
5 and	10	12 and	24

For use in Rymer-Jones dual cable test.

1×15,576 equals	15,576	1×25,576 equals	25,576
2×15,576 equals	31,152	2×25,576 equals	51,152
3×15,576 equals	46,728	3×25,576 equals	76,728
4×15,576 equals	62,304	4×25,576 equals	102,304
5×15,576 equals	77,880	5×25.576 equals	127,880
6×15,576 equals	93,456	6×25,576 equals	153,456
7×15,576 equals	109,032	7×25,576 equals	179,032
8×15,576 equals	124,608	8×25,576 equals	204,608
9×15,576 equals	140,184	9×25,576 equals	230,184

No. 4. Kennelly (p. 61, Barker's Handbook, 1903).

$$\text{Current radio: } \overset{C_1}{1} : \overset{C_2}{4} : \overset{C_3}{9} \text{ —scale zero.}$$
$$\quad R_3 \quad R_2 \quad R_1$$
$$X=\frac{R_3+R_1}{2}-4(R_3-R_1)$$

NOTE.—Two calculations, approximate for 27 and 18 milliamperes.

$$\left\{\begin{matrix} 3 \text{ ma.} : 12 \text{ ma.} : 27 \text{ ma.} \\ 2 \text{ ma.} : 8 \text{ ma.} : 18 \text{ ma.} \end{matrix}\right\}$$

See practical tests appended hereto.

No. 5. Kennelly. Page 62, Barker's Handbook, 1903.

$$\begin{array}{lccccc} & C_1 & & C_2 & & C_3 \\ \text{Current ratio:} & 1 & : & 4 & : & 16 \ \text{—scale zero.} \\ & R_3 & & R_2 & & R_1 \end{array}$$

$$X=\frac{R_3+2R_1}{3}-2(R_2-R_1)$$

Note.—This test not limited to 25 milliamperes, according to Kennelly.

Note.—Two calculations, approximate for 32 and 48 milliamperes.

2 ma. : 3 ma. : 32 ma.} See practical tests annexed.
3 ma. : 12 ma. : 43 ma.}

Note for approximating.—It is noticed that the difference between readings grows less as ma. increases; also that 12, 16, 20, 24 differ by 4; hence, 32 greater by two periods of 4 than 24 which is measured.

Also, that 48 is greater by 6 periods of 4 than 24 which is measured.

Diminish the difference between fours as they increase, being guided by the differences measured between 12 and 24.

Heavy solid black curve shows estimated 96 ohms; heavy dotted black curve shows that it should have been 103 ohms. Fine solid curve shows estimated curve, 196 ohms; fine dotted curve shows that it should have been 203 ohms.

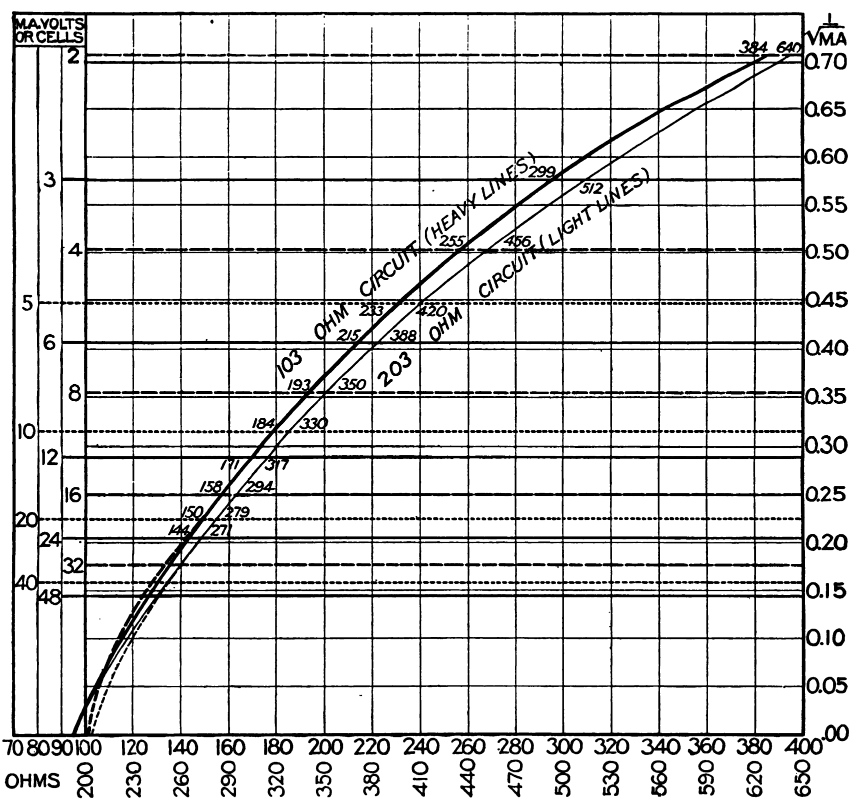


Fig. 11–42.—LONG SUBMARINE CABLES, TESTING, CURVE SHEET FOR JONA AND OTHER GRAPHS.

Two Actual Laboratory Tests, One With 103 Ohms in Circuit, the Other With 202 Ohms in Circuit, Ends Terminating in Glass Jar Filled With Sea Water, Exposure of Ends Being: 102 Ohms, ½ Inch; and 203 Ohms, Copper Flush With Insulation.

[100 ohms in rheostat—2 milameters 3 ohms=103 ohms in circuit.]

Measurements.

[One-half inch core exposure. Scale zero.]

ACTUAL TEST.

Milliamperes.	Ohms.
24	144
20	150
16	158
12	171
10	164
8	193
6	215
5	233
4	255
3	299
2	384

Calculations.

CANN'S TRIPLE TEST.

Scale zero.

109
110
112
109
105
86

6)631

Average 105.2 ohms.

Highest 112 ohms.
Lowest 86 ohms.

2)198 ohms.

Average 99 ohms.

RYMER-JONES DUAL TEST.

Scale zero.

102
97.1
103.5
102.5
107.5
96.4
(84) excluded.
(54) excluded.

6)409.0

Average 101.5 ohms.

Highest 107.5 ohms.
Lowest 96.4 ohms.

2)203.9 ohms.

Average 101.9 ohms.

KENNELLY'S.

Scale zero.

1 : 4 : 9 milliamperes, ratio of.
Can get 2 calculations.
3 ma. : 12 ma. : 27 ma.=100 ohms.
2 ma. : 8 ma. : 18 ma.=108.5 ohms.

2)208.5 ohms.

Average 104.2 ohms.

KENNELLY'S.

Scale zero.

1 : 4 : 16 milliamperes, ratio of.
Get two calculations.
2 ma. : 8 ma. : 32 ma.=110 ohms.
3 ma. : 12 ma. : 48 ma.=106 ohms.

2)216

Average 108 ohms.

Note.—See curve sheet for Jona curve.

General average of all the 103-ohm test, scale zero.

105.2
99.0
101.5
101.9
104.2
108.0
96.0 Jona curve.

7)715.8

General average 102.2 ohms.

Second test: 200 ohms in rheostat—2 milliamperes 3 ohms=203 ohms in circuit.

Measurements.

[Core flush. Scale zero.]

ACTUAL TEST.

Milliamperes.	Ohms.
24	270.6
20	278.6
16	292.6
12	316.8
10	330.0
8	350.0
6	388.3
5	420.5
4	455.6
3	512.4
2	640.0

Calculations.

[203 ohms circuit.]

CANN'S TRIPLE TEST.

Scale zero.

215
203
211
216
204
209

6)1,258

Average 209.7 ohms.

Highest 216
Lowest 203

2)419

Average 209.5 ohms.

BYMER-JONES DUAL TEST.

Scale zero.

199
199.5
206.7
206.4
190
185
195
(169.4) excluded.

7)1,381.6

Average 197.4 ohms.

Highest 206.7
Lowest 185

2)391.7

Average 195.8 ohms.

KENNELEYS.

Scale zero.

1:4:9: milliamperes, ratio of.
Can get 2 calculations only.
3 ma.: 12 ma.: 27 ma.=181.5 ohms.
2 ma.: 8 ma.: 18 ma.=202.5 ohms.

2)384

Average 192 ohms.

KENNELEYS.

Scale zero.

1:4:16: milliamperes, ratio of.
Can get 2 calculations only.
2 ma.: 8 ma.: 32 ma.=207 ohms.
3 ma.: 12 ma.: 48 ma.=213.2 ohms.

2)420.2

Average 210.1 ohms.

NOTE.—See curve sheet for Jona curve, 196 ohms.

General average of all the 203-ohm test.

209.7	
209.5	
197.4	
195.8	
196.0	Jona curve.
192.0	
210.1	
7) 1,410.5	
201.5	general average.
203.0	ohms exact.
Error, 2.5	ohms.

Refer to the Jona curve sheet, where 16 mil amperes are used: Then $\sqrt{16}=4$; inversely $\frac{1}{4}=0.25$, which will be found opposite 16 on right-hand side of curve sheet, indicating that the resistance of the fault has been reduced to $\frac{25}{100}$ of itself.

Again, where 4 mil amperes are used: $\sqrt{4}=2$; inversely $\frac{1}{2}=0.50$, which will be found on right-hand side of the curve sheet opposite 4, which shows the resistance of the fault has been reduced to $\frac{50}{100}$ of itself.

It will again be observed by noting the curve that as the tests approach 24 mil amperes the resistance which is sought is reduced.

Solicitude for the safety of the instruments and cable, together with experience, has shown that 24 mil amperes should not be exceeded.

Casual observation of the fine current lines on the Jona curve sheet, together with knowledge of the direction of the curve, shows that after 24 mil amperes are passed the fine solid and dotted lines are close together, even though the differences are 8, as compared with differences of 4 between 24 and 12, and 2 between 12 and 6, and 1 between 6 and 2, while the curve itself is more perpendicular, with a consequent decrease in the rate at which the resistance is being reduced.

The above shows that after passing 24 very great increase in current is necessary to produce a small decrease in resistance. Hence, the curve below 24 on the sheet is approximated as being the most practicable.

Referring to the numbers on the right-hand side of the curve sheet, which are the results of 1 divided by the square root of milliamperes used, it will be found that they increase from the bottom to the top of the page, and that the distance apart is regular, while the distance apart of the fine current lines is irregular.

To eliminate all resistance in the fault would require an infinitely large current, as the resistance of the fault is proportional to the numbers on right-hand side of the curve sheet, i. e., no resistance on the bottom line, increasing to 0.70 of the full resistance of the fault at 2 milliamperes.

Taking the two examples noted above and deducing from percentage of fault to mil amperes necessary—

Let X=milliamperes necessary.

Then: $.50=\frac{1}{\sqrt{x}}$ $\therefore$ $.50\ \sqrt{x}=1$ $\therefore$ $\sqrt{x}=\frac{1}{.50}=2$

$\sqrt{x}=2$, squaring both members x=4 agreeing with numbers as printed on curve sheet.

Again: $.25=\frac{1}{\sqrt{x}}$ $\therefore$ $.25\sqrt{x}=1$ $\therefore$ $\sqrt{x}=\frac{1}{.25}=4$

$\sqrt{x}=4$, then by squaring both members $x=16$.

Using the experience thus gained we know that $.00=\frac{1}{\sqrt{\infty}}$ or the milliamperes would have to be infinitely great to produce no resistance in the fault.

By way of comparison, however, we can find out the milliamperes necessary to reduce the resistance of fault to a very low finite quantity.

Question: How much current is necessary to reduce resistance of fault to .001 of itself?

$$.001=\frac{1}{\sqrt{x}} \quad \therefore \quad .001\sqrt{x}=1 \quad \therefore \quad \sqrt{x}=\frac{1}{.001}=1000$$

$\sqrt{x}=1000$, $x=1{,}000{,}000$ milliamperes, which is, of course, impracticable.

The above calculations in practice would be considerably upset, for a strong negative current, which is the current mostly used, would insulate or tend to insulate the exposed surface by covering it with hydrogen gas, for the stronger the current the more hydrogen is released. If positive current is used the copper is decomposed and the exposed end is covered with a cuprous or copper powder which, as well as the hydrogen, has an insulating effect; hydrogen gas, however, being more volatile escapes more easily except when formed in a very small aperture sealing it, in which case it is sometimes necessary to use the positive current to clear off the hydrogen.

Very small exposures sometimes are highly insulated by globules of hydrogen gas, using the negative current. In such a case, a very strong current would burn out the fault, after which a weaker current could be used for testing.

Current used should not exceed 24 milliamperes and in case of high resistance faults this could be obtained with the limit of 40 volts. These limitations are necessary for the safety of the cable.

HANDY FORMULA FOR TESTING SUBMARINE CABLE FOR BREAKS OR DEAD GROUNDS.

[Not metallic circuit.]

No. 6. Page 132 Baines Beginner's Manual, second edition; page 145 Fisher & Darby, third edition, for Jordan and Schonau's modification, of Kenneley's and Anderson's earth overlap test.

The plain earth overlap test has been previously explained in this chapter.

Tests are taken by each station under similar conditions or bridge ratio, battery power, etc., until preconcerted number of observations have been completed.

Stations Numbered 1 and 2.

[First operation—Preliminary test.]

Station 2 cable grounded.
Station 1 measure resistance (R).
Station 1 cable grounded.
Station 2 measure resistance (R^1).

[Second operation.]

Station 1 unplug in bridge $R+R^1$.
Station 2 unplug in bridge $R+R^1$.
Station 1 insert resistance=R^1 between bridge and cable—call it (r).
Station 2 insert resistance=R between bridge and cable—call it (r^1).

[Third operation—For test.]

Station 2 ground cable, leaving r^1 in circuit.
Station 1 obtain balance in bridge by increasing or decreasing the value of r.
Station 1 ground cable, leaving r in circuit.
Station 2 obtain balance in bridge by increasing or decreasing the value of r^1.

This operation to be repeated alternately by stations 1 and 2 until balance is obtained without having to make further changes in resistance r or r^1.

Then the resistance to the fault from station 1 is—

$$\frac{L+r^1-r}{2}=\text{ohms to fault.}$$

and from station 2:

$$\frac{L+r-r^1}{2}=\text{ohms to fault.}$$

L=length of perfect cable in ohms.

The sum of these two results should equal the C. R. of the perfect cable.

For the purpose of checking the battery, which should be the same at both ends of the cable, a milliammeter should be inserted in the cable and the readings taken, and when the fault has been electrically placed in the center of the cable the readings of the milliammeters at both ends of the cable should be the same.

JORDAN AND SCHONAU'S MODIFICATION.

For a confirmation of the foregoing tests, another series was taken to a diminished resistance in C. The inserted resistance r at station 1 being the lowest, viz, 4,124 ohms, each end could be reduced 4,000 ohms in C (arm of bridge, see diagram). The amount therefore in C, at both stations, to which balance would be obtained by the respective adjustments of r and r^1 was made 5,810 ohms.

It will be seen from the following results that r and r^1 were proportionately diminished.

Station 1.	Station 2.
1st test, r 166	r^1, 1,334
2d test, r 162	r^1, 1,334
3d test, r 162	r^1, 1,334
4th test, r 162	r^1, 1,334

The resistance to the fault from station 1 is:

$$\frac{8800+1334-162}{2}=4,986$$

and from station 2:

$$\frac{8,800+162-1,334}{2}=3,814$$

which results are the same as those obtained with 9,810 ohms in C, for the first series of tests.

4,986+3,814= ohms total 8,800

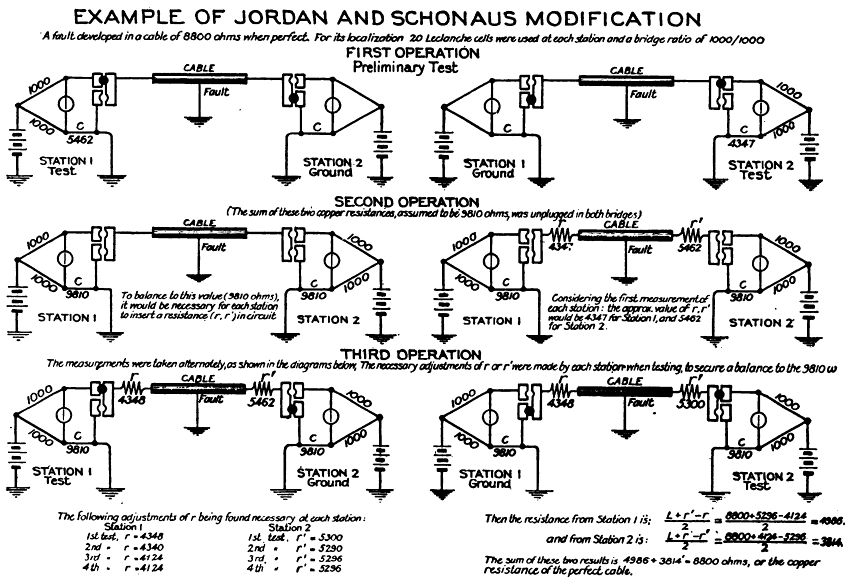


Fig. 11–43.—LONG SUBMARINE CABLES, TESTING, JORDAN AND SCHONAU'S MODIFICATION OF EARTH OVERLAP TEST, DIAGRAM OF CONNECTIONS.

INSTRUCTIONS FOR SHORE STATIONS DURING LAYING OR REPAIR OF CABLE.

Instructions will be given to look out for ship's call at a specified time. Connect up for receiving, and keep close watch in order to answer promptly.

Ship will give instructions regarding necessary connections. These instructions *must be implicitly obeyed,* and with rigid accuracy as to time.

Timepieces are to be set according to ship's instructions, and frequent comparisons with ship's time made in case timepiece is not regular.

Instructions to "free the end of the cable for so many minutes" would be abbreviated "Free —— min." During this period especial care must be taken that the end is well insulated, and on no account must the conductor be permitted to touch anything.

Instructions to "Earth (ground) the cable for so many minutes" will be abbreviated "Earth —— min." The end of the conductor, or its binding screw, will then be directly and securely connected to the cable armor for the time specified.

After each order is executed for the time specified, connect up for receiving and await next order. Should no communication come from the ship after 15 minutes, begin at the hour and free the cable for 15 minutes, then earth for 15 minutes, then connect up for receiving during the remaining half hour. Continue this routine every hour until communication is restored, or twelve hours has elapsed. If there is still no communication, connect up for receiving and keep close watch for ship's call.

In a book at the station will be kept a complete record of all changes in connections made and instructions received during laying and repairs and the exact time each was made. This record must be signed by the man on duty, with note of time he has been relieved. He will at the same time call attention of the one relieving him to any written note of instructions he has received from the ship.

Strict obedience to the foregoing instructions is enjoined.

Alaskan cable data.

[Weight of 1903 type.]

	Deep sea.	Intermediate.	S. E.
	Pounds.	*Pounds.*	*Pounds*
Whole cable in air (per knot)	3,605	6,787	21,620
Whole cable in air (per mile)	3,127	5,887	18,800
Whole cable in water (per knot)	2,328	4,812	....
Whole cable in water (per mile)	2,019	4,174	....
MATERIALS.			
Iron wire (per knot)	2,359	5,083	....
Iron wire (per mile)	2,046	4,409	....
Jute and compound (per knot)	888	1,341	....
Jute and compound (per mile)	770	1,163	....
Tape (per knot)	66	....	....
Tape (per mile)	57	....	....
Rubber (per knot)	177	....	....
Rubber (per mile)	153	....	....
Copper (per knot)	132	....	....
Copper (per mile)	115	....	....
Diameters ... inch	.81	.98	1.75
C. R. at 60° F. (per mile) ... ohms	7.39	....	....
D. R. at 60° F. (per mile) ... megs	1,418	....	....
Capacity (per mile) ... m. f.	.428	....	....
C. R. at 60° F. (per knot) ... ohms	8.52	....	....
D. R. at 60° F. (per knot) ... megs	1,230	....	....
Capacity (per knot) ... m. f.	.493	....	....
Breaking strain	14,570	19,790	....
Elastic strain	11,000	13,000	....

NOTE.—Alaskan type of 1904 has 215 pounds of rubber per knot.
Shore end is intermediate (11 No. 8 B. W. G. wires) with an outer armor of 13 No. 3 B. W. G. wires.

Weights (in pounds) submarine cable, Alaskan type, 1905.

	Per mile.	Per naut. mile.
Core:	*Pounds.*	*Pounds.*
Conductor	122.48	141.18
Pure Para	11.38	13.10
40 per cent compound	193.31	222.60
Tape	71.00	81.75
Total	398.17	458.63
Deep-sea cable:		
Core	398.17	458.63
Armor (16 No. 13 B. W. G. wires)	2,232.00	2,570.00
Jute, tar compound, and cutch	656.00	755.40
Total	3,286.17	3,784.03
Weight in water	2,098.00	2,416.00
Intermediate cable:		
Core	398.17	458.63
Armor (11 No. 8 B. W. G. wires)	4,690.00	5,400.20
Jute, tar compound, and cutch	1,138.00	1,310.30
Total	6,226.17	7,169.13
Weight in water	3,948.00	4,546.00
Shore-end cable:		
Core	398.17	458.63
Armor (first, 11 No. 8 B. W. G.)	4,690.00	5,400.20
Armor (second, 14 No. 3 B. W. G.)	13,002.00	14,972.00
Jute, tar compound, and cutch	3,430.00	3,949.00
Total	21,520.17	24,779.83
Weight in water	15,192.00	17,495.00
Specific gravity:		
Pure Para	....	.9250
40 per cent compound	....	1.5903

INDEX.

REMARKS.

All those to whom this manual is issued are requested to observe that the index consists of three parts, namely: Chapters, subjects, and illustrations; and that to find a subject or illustration it is first necessary to locate the chapter. This can be readily accomplished, as chapter numbers appear on each leaf of the manual.

An alphabetically arranged list of all Signal Corps apparatus and supplies appears in chapter 8, beginning on page 1.

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SUBJECT INDEX.

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